LAKE STATES ASPEN REPORT NO. 11

ASPEN FOR CORE STOCK

BY
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U. S. DEPARTMENT OF AGRICULTURE
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FOREWORD

During and since World War II, there has been increasing interest in aspen (Populus tremuloides) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up-to-date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

Report Number	Subject
1	Aspen Properties and Uses
2	Aspen Availability and Supply
3	Logging Methods and Peeling of Aspen
4	Milling of Aspen into Lumber
5	Seasoning of Aspen
6	Aspen Lumber Grades and Characteristics
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AGRICULTURE - MADISON

REPORT NO. 11

ASPEN FOR CORE STOCK [1]

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INTRODUCTION

During recent years, aspen has been used in the Lake States region for a number of products. The war years in particular showed a marked increase in the use of aspen for pulpwood, box lumber, and many other wood products. The annual cut of aspen lumber in the region increased from approximately 67 million board feet in 1941 to 152 million board feet in 1946. In spite of this increased use, aspen still remains the only major tree species in the Lake States in which annual growth exceeds annual drain. It represents the major forest resource in this region that is presently available for sizable plant expansion if a reasonable balance is to be maintained between growth and drain.

The aspen type occupies 20 million acres or approximately 39 percent of the commercial forest area of the Lake States. The saw-timber volume is estimated to be about 6½ billion board feet in trees 9 inches d.b.h. and over, with a larger volume in smaller sized trees. It is estimated that the present aspen resource could sustain an annual cut in saw timber of approximately 300 million board feet. The present and future availability of aspen saw timber suggests that suitable uses should be developed for this resource in keeping with the most favored characteristics of the wood.

Within recent years considerable interest has developed in the use of aspen for core stock in furniture manufacture and allied uses. The characteristics of the wood adapt it for this use when it is well manufactured, properly seasoned, and of the right grade. Several large panel and plywood producers are now using aspen for lumber core stock. Many furniture manufacturers are also using considerable volumes of aspen core stock.

1/ Aspen as used in this report includes large tooth aspen (Populus grandidentata) and trembling aspen (Populus tremuloides).
2/ Now Industrial Forest Engineer, Duluth 2, Minnesota..

ASPEN SUITABLE FOR CORE STOCK

Lumber core stock is a fabricated product formed by edge-joining random width lumber cuttings with glue to form a panel of specified width, length, and thickness. It is produced both in special core stock plants and in the users' plants by a variety of manufacturing methods and types of equipment, using various kinds of glue depending upon the product to be manufactured. Lumber core stock is generally used as a center ply for three or five ply veneered stock. Lumber core stock is produced in several grades and in thickness from 3/8-inch rough, or 3/16-inch S2S, and up in standard thicknesses.

Core stock produced from lumber has many uses in the industrial field. One of the main ones is in furniture manufacture. The increased use of veneered products in furniture manufacture has stepped up the need for lumber core stock. Large amounts of lumber core stock are also used in the production of veneered fixtures and panelling, and in all veneered products where a stable center ply of heavier thickness than veneer is required to develop the maximum utility or appearance of the product.

Aspen Wood Has Properties Desired in Core Stock

To be acceptable for core stock, wood must have certain properties. Among the most important of these are: (1) the gluing characteristics of the wood, (2) a low shrinkage and swelling factor, (3) low specific gravity, (4) straight grain, (5) uniformity of texture or lack of contrast between springwood and summerwood, and (6) ease of machinability in the major wood-working processes.

Aspen wood rates well in all of these major requirements. It produces a strong glue line with any of the standard type glues. It has a very low shrinkage and swelling factor; it is superior to many more highly prized woods in this respect. The machining qualities of aspen wood are very similar to those of other soft-textured hardwood species. In other words, under proper conditions adjusted to the wood itself, it can be finished to satisfactory smoothness for all ordinary uses.

In addition to these requirements, aspen wood has several other properties which make it desirable for core stock material. It has a very fine, uniform texture. It is moderately light but tough. It is superior in shock resistance to such moderately light woods as eastern spruce, cottonwood, yellow poplar, eastern hemlock, and light woods such as basswood, balsam fir, and white pine. It has about the same bending strength as eastern white pine. In softness and uniformity of texture, it is about equal to basswood and yellow poplar. Its stiffness is a little less than that of the other species mentioned. In common with other light to moderately lightweight woods, aspen has a relatively low screw-holding capacity, but it is also relatively free of splitting and when the proper size screws and lead holes are used, good results are obtained.

Except for an appreciable amount of collapse in boards cut from the inner portion of certain trees, aspen seasons rather quickly and

easily to a low moisture content provided proper practices are followed.

Availability of Aspen Wood

Aside from having desirable physical and mechanical properties, a wood must be readily available at reasonable cost to be of interest to core stock producers.

While some of the higher quality cabinet woods have machining characteristics which make them very desirable for core stock, the higher cost of these woods and other factors make them generally unavailable for this use. However, the veneer process has extended the supply of the better cabinet species, and increased use of veneer has expanded the demand for suitable core stock woods.

Aspen wood is available in sufficient quantities to provide a steady flow of raw material of a quality suitable for core stock production if properly graded for this use. It is competitive in price on a grade basis with other species commonly used for this purpose. It is well adapted to industrial uses in which the demand is for small and medium-size cuttings and in which the limiting defects found in aspen can be eliminated before fabrication.

Aspen Can Be Used for Core Stock

Through no inherent characteristics of the wood itself, aspen lumber produced on a mill-run basis has acquired an unfavorable reputation as general industrial lumber. This has been due mainly to the small size of the average tree, the common 100-inch log length, the low percentage of upper grades, and the generally poor manufacture and seasoning practices of the average small portable mill. However, since aspen lumber is now being produced in considerable volume in permanent mills with modern dry kiln facilities, much of the criticism on the latter point is being overcome. Grading and production of standard length lumber would help to overcome the other objections.

Mill-run aspen lumber from old-growth stands frequently produces up to 30 percent No. 1 Common and Better lumber; 35 percent No. 2 Common, with the balance No. 3 Common and below. The grade of No. 2 Common and Better in aspen (NHLA rules) produces a satisfactory grade for production of core stock.

Information developed for a representative group of wood-using industries showed that the size of cutting required by these industries was considerably smaller than is popularly believed. Requirements were so moderate that 50 percent of the volume of cuttings used was in widths of 4 inches or less and 80 percent in cuttings 48 inches and under in length. Lumber produced from small timber can be used economically to meet the needs of ordinary wood-using industries if the cost-price per cutting for labor and material does not exceed that when using higher grade lumber. Grade is important but it can be minimized by carefully limiting defects

for the use to which the cutting is to be put. In the production of core stock, attention and study should be given to the needs of various users of the product. Cutting to specific requirements as to size and grade of stock will increase the yield of salable product in the case of aspen lumber. Since the utilization of short-length lumber is always a problem to any wood-using industry, this question should receive particular attention when using aspen.

METHODS OF MANUFACTURE

Drying of Lumber

Lumber must be dried to an average moisture content of 5 to 6 percent on an oven-dry basis before being fabricated into core stock. Aspen lumber dries readily in modern dry kilns to this moisture content in approximately six days for 4/4 lumber without prior air drying. In this respect aspen is classed as one of the less difficult hardwoods to dry satisfactorily with a minimum amount of degrade.

During the drying process, certain stresses are set up in the wood which must be relieved before the wood is in condition for use in core stock. Casehardening is a common form of internal stress in wood that must be corrected before the wood is discharged from the dry kiln. This is usually accomplished by admitting steam into the kiln for the required length of time at the end of the drying cycle. Following removal from the kiln, the dried lumber should be allowed to cool off or condition in protected storage for two or three days before entering the manufacturing process in order that internal stresses in the lumber may be reduced.

The most common defect encountered in the kiln drying of aspen is collapse. This occurs most frequently in darkened heartwood and in wood immediately inside of the white sapwood area. Such collapsed wood is likely to have a high green moisture content and its occurrence may be associated with incipient decay, although the exact cause is unknown. Because of these slower drying areas, machining should not be done until tests show that the drying period has been sufficient to obtain a uniform moisture content. The degrade caused by collapse is not extensive in most cases, but such affected material must be removed in subsequent cutting operations when the better grades of core stock are being made. Aspen seasons with few splitting, checking, warping, twisting, or other common drying defects. Properly dried aspen is very stable and is therefore well adapted to core stock production.

Where the amount of material processed justifies the cost, modern equipment for handling lumber is a paying investment and eliminates costly manual operations. Powered transfer cars and lumber lifts are available which can handle an entire kiln truck of lumber with a minimum of manpower and expense.

Shop Methods in Production of Core Stock

Aspen wood can be fabricated into core stock by standard methods. Preparation of the glue joint may be made in any one of several ways. The modern chain-feed, straight-line ripsaw, when properly fitted, will produce a satisfactory glue joint in aspen. The swage-set saw is believed to produce the cleanest cut in aspen, but the spring-set saw gives equally good results when accurately fitted. Satisfactory stock for gluing may also be obtained with the modern glue jointer and the hand jointer. The latter type of equipment requires a skilled operator for satisfactory results. The principal requirements for a good glue joint or surface are that it be straight, smooth, and square with the cutting being worked.

Glue equipment consists of some type of glue spreader for coating the prepared edge of the cutting and a clamping device for pressing the cuttings together and holding them until the glue has set. There are several types of spreaders and presses, ranging from simple hand-operated equipment to modern continuous-type core gluers employing steam or high-frequency electric current for setting and drying of the glue line. A common type of equipment found in many plants is the roll glue spreader and the multiple section clamp carrier. The more modern units of this type of equipment are motor driven. A fairly high rate of production is possible with skilled operators. The continuous type core gluers are a more recent development that give promise of high production rates with a minimum of manpower. They are a high-cost unit, however, and are best suited to plants of large capacity.

There are various types of glue used in the manufacture of core stock. The type used should be in keeping with the use of the product to be manufactured. Thus, if the end product is subject to alternate wetting and drying, a waterproof glue should be used in laying up the core stock. For most uses where lumber core stock is used, however, the requirements are mainly for a water resistant glue. If cold-setting glues are used in the core stock operation, information should be available on the reaction in the glue line if the veneer is to be laid up by the hot press method. Aspen produces a strong glue line with either cold-setting or hot-setting glues, and press pressures in veneering should be comparable to those used for the same density woods of other species. The press pressures will depend upon the faces and crossbands as well as on the cores. In general the assembly will require gluing pressures higher than those that are just sufficient to glue aspen to aspen.

Core stock production lends itself to a high degree of mechanization if the volume output is sufficient to justify the plant investment required. It is also possible to operate efficiently in the small shop with a minimum of mechanical handling equipment if the shop is efficiently laid out and organized for this type of production.

Machining Aspen Wood

Aspen wood machines best in most of the wood-working processes at about

6 percent moisture content based on oven-dry weight. Planing tests conducted on aspen indicate that a 30-degree knife cutting angle producing not less than 16 knife marks per inch gives good surfacing results. Aspen wood planes much better as a rule with a light cut of about 1/32 inch than with heavier cuts. For best smoothness of surface, cuts in excess of 1/16 inch should be made in two operations or runs. All soft-textured woods are more prone to produce fuzzy grain than the more dense hardwoods, and aspen is no different in this respect than other woods of similar texture.

Shaping is an important operation in some types of furniture manufacture where the edges are not veneered but are worked to some form or pattern. There are relatively few woods, however, that are outstanding in this quality and for the most part they are the better cabinet woods such as mahogany, birch, and hard maple. Additional experimental work needs to be done on shaping to determine the best method of producing smooth-shaped edges in soft-textured woods.

In general, the machining qualities of aspen are very similar to those of other soft-textured hardwood species. Careful attention to details of machine setting will usually produce satisfactory results in the machining of aspen.

Finishing to the User's Requirements

The production of core stock should be closely correlated with the user's requirements since the manner in which it is finished must fit into the subsequent operations that must be performed on it. In large measure, core stock is a custom-made item and is laid up in the size that is wanted for a particular purpose. This is especially true of that going to the furniture trade. There are, however, certain stock items and sizes that are produced in large quantities for the panel and plywood trade.

Core stock is frequently produced and shipped from the same plant in several conditions of surface depending upon the requirements of the user. Rough or hit and miss surfaced stock is frequently furnished to using plants that are fully equipped to complete the final surfacing operation. Stock is less subject to damage in transit when shipped in this form, as most scratches will surface out in the final planing. Finish-surfaced stock is frequently furnished to users that are not equipped to perform this operation or where it is desired to use it directly in the veneering process upon arrival. Sanded and cross-banded stock is furnished only infrequently since these operations are commonly performed as a concurrent operation with laying of the face veneer.

Customers' specifications often extend to the type of glue to be used in laying up the core stock and to the kind of joint that is acceptable. A common specification at one time was for a tongue and groove joint such as that produced on the glue jointer. However, this specification is now frequently ruled out in favor of the straight butt or edge joint.

Another common type of joint sometimes specified is the tapered dovetailed joint produced in a specialized type of equipment which also acts as a press and panel-forming unit at the same time.

An essential part of core stock production is careful attention to the details of manufacture, and inspection to assure adherence to established grades and specifications.

EQUIPMENT FOR CORE STOCK PRODUCTION

Cutting Equipment

Core stock production is essentially a process of reducing lumber to cuttings of a particular size and grade and reassembling them into panels. The cutting equipment most commonly used in a core stock plant includes ripsaws, cut-off saws, and frequently a resaw. If the glue joint is produced in the ripping operation, the most common type of equipment used is the chain-feed, straight-line ripsaw. The modern, direct motor-driven saw of this type is a precision piece of equipment, capable of exacting work when properly fitted and maintained. The ripping operation reduces the lumber to the required width and removes certain types of defects that are not admissible in the grade of stock being made, as well as producing the glue surface. Power-feed equipment is essential in this operation if adequate production is to be obtained.

The cut-off saw performs two essential operations in core stock production: (1) reduces the cutting to proper length and (2) eliminates defects that are not admissible in the grade of the stock being cut. There are several kinds of cut-off saws that are entirely suitable for this operation in either the swing or radial type. Cross-cutting equipment should be well maintained and fitted to produce a smooth cut. The double cut-off type saw is frequently employed to square trim the glued-up panel prior to shipment. The modern chain-feed, direct motor-driven, double cut-off saw is a versatile piece of equipment that can perform several operations when properly fitted.

The resaw in the core stock plant is generally a utility piece of equipment rather than a production item. It may be either the vertical or horizontal type and is most frequently used to rework heavy stock to thinner dimensions. Appreciable savings are possible by this method if the heavy stock has been kiln dried to the proper moisture content and freed of casehardening.

Surfacing Equipment

The surfacing equipment required in a core stock plant is dependent upon the plan of operation followed and the condition or surface of stock to be shipped. Many plants lay up core stock from rough cuttings without any preliminary planing or sizing. While there are some advantages to this practice, it frequently results in degraded stock at the time of final surfacing due to exposure of defects that were not apparent in the

rough cutting. In preparing aspen lumber for use in core stock, it is frequently good shop practice to give the rough lumber a light hit and miss or equalizing planing as a first operation. This planing operation usually exposes any defects that will require subsequent removal and results in less reworking of completed panels. A modern double surfacer of the long bed type or the equalizing straight-o-plane are satisfactory types of equipment for this operation.

The cabinet type single or double surfacer with wide bed opening is a satisfactory type of equipment for finish surfacing of glued-up panels. Since in many instances where this operation is performed in the core stock plant the stock will be routed directly to the veneering process at the receiving end, every effort should be made to produce a smooth and properly sized panel. This will require adequate maintenance of equipment and a continuous inspection service to insure a satisfactorily finished product.

Other types of knife-cutting equipment frequently found in the core stock plant are glue jointers and hand jointers. Except in cases where the glue joint is produced by one of these two methods, these two items of equipment are generally considered as utility items rather than production equipment.

Miscellaneous Equipment

Other types of equipment frequently found in the core stock plant in addition to the gluing equipment already discussed are conveyors, hand or platform trucks, glue mixers, and saw and knife sharpening equipment. Sanding equipment is sometimes found in the core stock plant as a utility type of equipment.

The general plant layout and the amount of daily production will govern the number of units of equipment required in the core stock plant. This can only be determined on the basis of each specific case and is beyond the scope of this report.

GRADING OF CORE STOCK

Description of Grades

The following grading standards for core stock were issued by the United States Department of Commerce through the National Bureau of Standards at the instance of the Plywood Manufacturers Association, and became effective in July 1942.

Cores or Centers, Sawn

Grade A (Clear) - A core of any designated wood with any specified type of tight glued joint and random widths, full length strips not over 4 inches wide. Discolorations shall be admitted, but it shall be clear of defects.

Grade No. 1 (or Regular) - A core of any designated wood with any specified type of tight-glued joint and random widths, any one strip to be not over 4 inches wide. Sound knots, discolorations, and butt-joint strips, other than outer edges, shall be admitted. Open defects, if securely patched, shall be admitted.

Grade No. 2 (or Clear Edge) - A core of any designated wood in either "A" or "No. 1" grades, with edges clear of defects to permit shaping (or molding) to a depth of 1½ inches on all edges.

Specifications other than standard grades are frequently drawn to suit the particular requirements of the user. A common specification of this type calls for a reduced width of strip or location of sound defects, etc.

Aspen is frequently produced and sold under the commercial standard grading rules for hardwood dimension lumber, and when so produced and sold, in glued or unglued stock, the grade requirements for flat stock hardwood dimension are applicable. The grades under this specification are for Clear, Clear one face, Paint, Core, and Sound. These grading standards were issued by the United States Department of Commerce, through the National Bureau of Standards, at the instance of the Hardwood Dimension Manufacturers Association, and became effective in October 1936.

SUMMARY

To an increasing extent, aspen must be looked to for any sizable expansion in plant capacity of wood-using industries in the Lake States region. Probably much of the disfavor associated with this species in the past has been due to lack of basic information on suitable uses for aspen, poor milling, and improper seasoning. Because of its favorable physical and mechanical properties and its wide availability in suitable grades and at reasonable cost, aspen wood holds considerable promise as a material for the manufacture of core stock. An added advantage is that it can be fabricated by standard methods and with standard equipment.

LAKE STATES ASPEN REPORT NO. 12

DIMENSION STOCK AND OTHER USES OF ASPEN

—BY—

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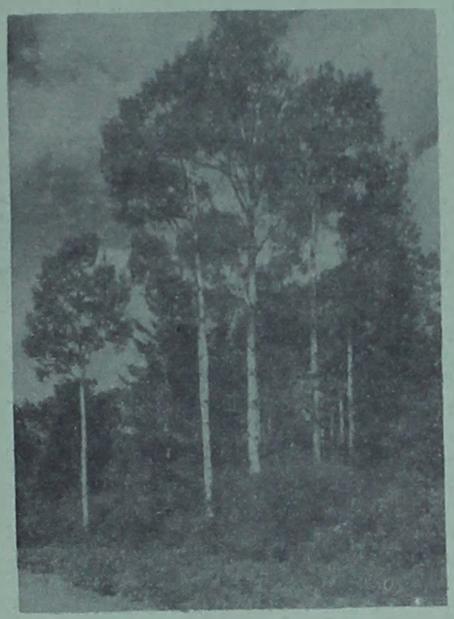

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FOREST SERVICE

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REPORT NO. 12

DIMENSION STOCK AND OTHER INDUSTRIAL USES OF ASPEN

By

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INTRODUCTION

Utilization of aspen for pulpwood, excelsior bolts, veneer logs and lumber has increased steadily during the past 10 years. This was particularly true during the war years when, because of the scarcity of other timber, aspen entered many new phases of utilization. In the lumber field alone the wider acceptance of aspen has been reflected in an increase in the annual production from 67 million board feet in 1941 to 152 million board feet in 1946. It is estimated, however, that aspen stands in the Lake States can provide an annual cut of at least 300 million board feet of lumber.

With general improvement in the lumber supply after the war a considerable slump in the utilization of aspen lumber occurred. Aspen is the only specie in the Lake States in which growth far exceeds the cut. As other northern timber species -- maple, birch, and hemlock -- become progressively depleted, the importance of aspen as a source of raw material for local wood-using industries, should increase.

This report deals with the use of aspen in the manufacture and utilization of dimension stock. It also explores a number of other present and potential industrial outlets for aspen.

DIMENSION STOCK

Definition of Dimension Stock

Dimension stock is flat or square wood-stock, varying in size from 1/2 to 6 inches in thickness, 1/2 to 8 inches in width, and up to 8 feet in length. The stock may be green, air-dried or kiln-dried, and either hardwood or softwood. Dimension stock may be rough or dressed, cut to the approximate size required for the various products of woodworking plants, or it may be furnished refined to conform to specific requirements of the user. In some instances it may be glued and in a highly finished form, ready for final assembly.

Sometimes a distinction is made between dimension stock and "ready-cut stock." In this case the latter is defined as material fabricated to the exact requirements of the user, ready for final assembly into a finished product, while the former is considered as rough or only partially fabricated material. Dimension stock is also produced and sold under a variety of other names, such as squares, blanks, cut-to-size stock, chair and leg stock, etc. The term dimension stock, however, should not be confused with the term "demension" as applied to heavier lumber or plank, used in general construction.

Industrial Uses of Dimension Stock

It has been estimated that as much as 90 percent of all hardwood lumber produced in the United States is further remanufactured into some finished product by wood-using industries. Of the total amount used only a small percent is consumed in widths of 5 inches or over, and in lengths in excess of 8 feet. More than 80 percent of the hardwood lumber is used in pieces under 4 inches in width and 2 feet in length (1,2,5). In other words, the bulk of hardwood lumber is ultimately converted into small dimension.

According to Sands and Malcolm (9), the consuming industries that may provide outlets for dimension stock are numerous and diversified. Some of these outlets are relatively new, and therefore their requirements are not standardized; examples of these are precut houses and house trailers. Other industries, such as sash, door, and millwork plants, have fairly stable and well known requirements for cut-up stock. Finally, the requirements of furniture plants, a very extensive potential market for dimension stock, are so diversified and changeable that they can be met only through individual contacts.

The major users of dimension material may be broadly classified under the following headings:*

TABLE 1 -- MAJOR USES OF DIMENSION STOCK

I. Factory House Group	II. Millwork Group
House trailers	Door and window frames
Prefabricated houseframing	Stock sash and doors
Precut houses	Screens, screen and combination doors
	Door core stock
	Shutters and blinds
	Moldings
	Interior trim
	Custom millwork

*Based in part on Sands and Malcolm, reference No. (9).

III. Household Equipment Group
- Furniture parts
- Radio cabinets
- Kitchen cabinets
- Refrigerators
- Laundry appliances
- Window shade rollers and slats
- Venetian blind slats

IV. Container Group
- Caskets and rough box
- Boxes and crates
- Trunks and luggage
- Pallets
- Cooperage

V. Implement and Appliance Group
- Agricultural implements
- Laundry supplies
- Apiary supplies
- Tools

VI. Miscellaneous Group
- Stepladders
- Grain and coal doors
- Turning squares
- Toys and novelties
- Picket and snow fencing

Manufacture of Dimension Stock

Most of the hardwood dimension stock is produced either from: (1) lumber, 8 feet and over in length, (2) bolts, i.e., short logs under 8 feet in length, and (3) mill residue. All aspen dimension is produced either from lumber or short bolts. Because of the small size and relatively low quality of aspen logs, aspen mill residue is poorly suited for conversion into small dimension material.

Milling of aspen logs and bolts. Aspen lumber in the manufacture of dimension stock is cut almost exclusively either in circular mills or with a splitter saw, followed by a horizontal resaw.

The single circular sawmill has the advantage of relatively low capital investment. It also presents the opportunity to obtain a higher yield of better grades, if the logs are turned in sawing. In practice, however, because of the small size of the aspen log, most mills cut aspen through and through, without any regard for grade of lumber. The per hour production in circular mills cutting aspen varies greatly with the mill and the size of the logs. The mills covered by this study report an hourly production of 4/4 lumber ranging from 500 to 1200 board feet.

The splitter-resaw equipment consists of a circular head saw, placed in a trough, that splits the logs as they are advanced toward it by the lugged chain, and a horizontal band resaw. The resaw reduces the half-logs into lumber of the desired thickness. The lumber is cut without any regard for grade, and reported output ranges from 3,000 to over 5,000 board feet of lumber per hour. The cost of such equipment is several times that of a single circular mill.

Telford and Malcolm (11) have also shown that for logs from which the single circular headsaw cuts 1,000 board feet of 4/4 lumber, the splitter-resaw mill will produce 1,075 board feet. On the cord basis it takes about $2\frac{1}{2}$ cords of 100-inch, woods-run aspen, 6 inches and over in diameter, to produce 1,000 board feet of 4/4 lumber. and

Mills cutting short aspen bolts in most instances use splitter-resaw equipment. Specially designed circular mills equipped with short-log carriage are also in use.

Yield and quality of lumber. Most mills manufacturing small dimension from aspen procure the logs by cord measure, in 100-inch length or in the form of bolts ranging from 48 to 52 inches in length. The minimum top diameter of logs and bolts is generally limited to 6, and in some cases to 8 inches.

Rees (7) has shown that in northern Minnesota in a typical lot of aspen logs, ranging from 5 to 15 inches in diameter, about one-third of the total lumber produced was in widths of 5 inches or less; about 50 percent was in widths of 6 to 8 inches, and the remainder in widths over 8 inches. Since diameter of the log at the small end determines to a large extent the width of lumber produced, this study indicates the desirability of eliminating logs under 8 inches in diameter, if the accumulation of narrow-width lumber is to be avoided. It should be pointed out, however, that the narrow boards, because they are cut from the sapwood part of the log, frequently comprise the best quality lumber. This may in part compensate for the higher cost involved in sawing and handling of such stock.

Grade rules for aspen lumber. Aspen lumber is seldom sorted into grades. This is especially true at the mills that saw it for their own use. The usual practice at such mills is to sort the usable lumber from the cull. The latter is determined by the minimum requirements for quality acceptable in the manufacture of their products (13). When lumber is purchased on the open market or from a sawmill it is usually sold on a mill-run basis.

Even though grading of aspen lumber is seldom practiced, there are at present four different sets of grading rules proposed for aspen. Two are the National Hardwood Lumber Association rules for aspen factory lumber, and aspen construction lumber; the third is the Northern Hemlock and Hardwood Manufacturers Association rules, under which aspen is graded as a softwood yard lumber; and the fourth set is special aspen rules drawn up by the Northern Pine Manufacturers Association. The latter rules are sometimes employed when aspen lumber is sorted for dimension stock. These rules provide for Select and Better grades, No. 4 and Better Common grade, and No. 5 Common. In most mills visited in the course of this study the cull lumber corresponded closely with the No. 5 Common grade, as established by the Northern Pine Manufacturers Association. In other words, all of the No. 4 Common and Better material was considered usable. Exceptions to this were a plant specializing in production of core stock and a plant engaged in production of specialty items, such as wooden heels and certain classes of turned articles. Such plants could use only material corresponding to No. 1 Common and Better grades.

From information obtained in a study conducted in Northern Minnesota, it was estimated that one million board feet of aspen lumber, from logs 6-inch and over top diameter, will have the following grade distribution (13):

TABLE 2 -- GRADE YIELD OF ASPEN LUMBER

Grade of lumber*	Volume in board feet	Percent
F & S	12,000	1.2
Selects	8,000	0.8
No. 1 Common	120,000	12.0
No. 2 Common	520,000	52.0
No. 3 A Common	200,000	20.0
No. 3 B Common	140,000	14.0
Total	1,000,000	100.0

Information obtained in the field from the producers indicates that the yield of better quality aspen lumber, i.e., No. 1 Common and Better grades, varies considerably in different lots of logs. The percentage of such higher grades, as reported by the producers, ranged from 10 to 30 percent of log yield. Plants utilizing all usable aspen lumber, i.e., an equivalent of No. 4 Common and Better grade, report 70 to 90 percent of log yield as usable stock.

Dimension Stock Plant Equipment

In addition to a head-rig, the equipment of a dimension stock plant consists of one or more of cut-off saws, ripsaws, resaws, and a planer. If assembled items such as core stock are manufactured, the plant may also have jointer and gluing equipment, consisting of a glue spreader, clamping devices, or modern steam or high-frequency electric, batch, batch-continuous or continuous-feed presses.

Since most aspen dimension is manufactured from lumber, the first operation consists generally of planing the boards on one or both surfaces. This is done to reveal hidden defects, which can then be eliminated more efficiently in subsequent operations.

Because of the relatively low value of aspen lumber, planed stock quite frequently is ripped the full length of the board. In one mill the surfacing and ripsawing operations are performed in a specially built combination planer and gang-ripsaw machine, thus saving one handling. In some mills the planed and sometimes the rough boards are first crosscut to the desired length and then ripped with a self-feed, straight-line type ripsaw.

*National Hardwood Lumber Association grades.

Where boards are ripsawed the full length the resulting strips are cross cut into the desired lengths. Each piece is handled individually and this gives a skilled operator an opportunity to eliminate the defects and to obtain the maximum amount of usable cuttings from each piece.

When aspen dimension stock is to be glued, the individual pieces may be passed through a jointer to obtain a flat and square edge, and a smoother gluing surface. However, for core stock a satisfactory glue joint may be produced with a straight-line ripsaw. Toole (12) reports that the swage-set saw is believed to produce the cleanest cut, but that the spring-set saw is also satisfactory, when accurately fitted.

Seasoning and Handling of Dimension Stock

For many uses dimension stock must be seasoned to below 10 percent of moisture content. This means that in these instances dimension material must be kiln-dried. An important exception to this is the lumber for boxes and crates, pallets, grain and coal doors, and similar industrial items. These products need not be seasoned below 15 percent moisture content, and the stock can therefore be air-seasoned.

Dimension stock from seasoned lumber. Because of the expense involved in handling small pieces, dimension stock of lower moisture content is generally produced from the preseasoned lumber or plank.

Aspen is considered to be a fast-drying species. During the active drying season, i.e., through the spring and summer months, properly piled aspen will dry to a thoroughly air-seasoned condition in 2 to 3 months, depending on the thickness of lumber. Lumber stacked in the fall and winter will not become completely air-dried until the following summer.*

Sapwood and normal heartwood of aspen can also be satisfactorily kiln-dried, either from green or air-seasoned condition. For such stock the schedule in Table 3 is recommended (10). This schedule should result in rapid drying with a minimum of degrade. In kilns with fast forced circulation 6/4 aspen lumber green from the saw has been dried to 6 to 8 percent of moisture by this schedule in 5 days. In kilns with slower circulation the drying time required will be proportionally longer.

*For complete information on air-seasoning and kiln-drying of aspen, see reference No. (10).

TABLE 3 -- DRY-KILN SCHEDULE FOR 4/4, 6/4, AND 8/4 LUMBER

Moisture content at which change should be made	Temperatures		Relative humidity	Equilibrium moisture content
	Dry bulb	Wet bulb		
Percent	°F.	°F.	Percent	Percent
Above 60	160	140	58	7.9
60	160	130	43	5.8
40	170	120	24	3.2
20 to 7	180	130	26	3.3
Conditioning treatment (2 to 4 hours)	180	170	80	11.4

If produced for market, hardwood dimension stock in smaller sizes is bundled to reduce handling charges and to protect the stock from damage in handling. Shipping bundles are either loose or rigid. In loose bundling the stock is tied with twine or soft wire. The chief purpose of such bundling is to group small pieces for more advantageous handling. Loose bundles, however, frequently become disarranged, because of the misplacement of pieces within the bundle. Rigid bundling involves tying of a number of compactly arranged pieces with wire or with metal band straps. Rigid bundles are generally tied with specially designed wire or tape-tying machines. Better grades of prefabricated stock must be carefully protected against any damage; such material is often wrapped in heavy paper and then strapped.

Unless immediately used, dry dimension material should be stored indoors to prevent an increase in moisture content. This can be best accomplished by bulk-piling, i.e., piling solid, without stickers. In this way the stock can be maintained at a proper moisture content for a long time, especially if the temperature is kept at 50° to 100° F. The temperature should be so adjusted that the corresponding relative humidity of the air will keep the wood at the desired moisture content. If humidity of the air is too low some form of humidification is desirable.

Dimension stock from green lumber and bolts. Handling of green dimension falls under two headings: (1) piling for air drying, and (2) piling for kiln drying.

To reduce handling, the smaller sizes to be seasoned are generally bundled. The bundles can be solid or stickered. In the solid bundles the pieces are in close contact with each other and are, therefore, well supported. On the other hand, poor circulation that results from this practice prolongs drying time and may lead to excessive staining.

The stickered bundles are formed by placing strips of wood 1/4 to 1/2 inch thick between each course of dimension stock. The material so separated dries more rapidly than a solid bundle, but considerable degrade may result because of warping.

In air-seasoning the bundles are then stacked outdoors or in the shed, each row of bundles separated by stickers of convenient sizes. Bundled material dries more slowly than loose dimension. The drying is non-uniform, and excessive molding and stain are common. Furthermore, as the stock dries and individual pieces shrink, some of the pieces in the bundles become displaced and are free to warp. With very small dimension, such as 1-inch squares, this cannot be avoided, since there is no other practical way of handling quantities of such stock in drying. With larger dimension the practice of bundling green material should be discouraged.

When handled as individual pieces, dimension stock can either be sticker-piled, cob-piled, lap-piled, or crib-piled. Sticker-piling refers to the method of piling where either regular or self-stickers are used, as in conventional lumber piling. Cob-piling is a form of piling where every layer consists of approximately the same number of pieces piled openly, i.e., with space left between the individual pieces, and where alternate layers are at right angles to each other. In lap-piling flat and relatively short stock is laid in a fairly straight, continuous pile of some definite width, so that the ends of each successive piece overlap the one below sufficiently for support; such piling requires only 2 tiers of stickers, one at each end of the pile. Crib-piling is a method of stacking dimension stock in which a center space is enclosed by 3 or more single tiers of stock, where the ends lap or cross each other, as in an old-fashioned rail fence.

To protect high-grade dimension stock from the effects of rain, snow, or direct sun, it is highly desirable to season it in a shed. The shed should have a good tight roof, and either open or louvered sides.

If dimension stock is to be kiln-dried, the method of piling is determined largely by the direction of air circulation in the kiln. The stock should be piled so that the air can pass through the load without encountering too many obstacles. Careful attention should be given to supporting the stock adequately to prevent warping. Only dimension and stickers of uniform thickness should be used in a pile. Drying of tightly bundled material in a kiln is generally unsatisfactory, because of slow and nonuniform drying that results from this practice.

No special drying schedules have been developed for kiln-drying aspen dimension. It is believed, however, that the schedule (Table 3) suggested for drying lumber can also be used with the dimension material.

SUITABILITY OF ASPEN FOR DIMENSION STOCK

The characteristics required of dimension stock material are dictated by the ultimate use of the stock, and are, therefore, quite variable. There are, however, certain considerations which are applicable to any wood used in the manufacture of dimension material. These may be grouped as economic factors, and machining characteristics and other physical properties of the wood that enter into successful manufacture of this wood into dimension stock.

Economic Factors

These involve consideration of cost of material, i.e., logs, bolts, or lumber, in relation to the yield of salable dimension material.

Cost of raw material. At the time of this study the prices paid for 100-inch aspen logs ranged from a low of 16 dollars a cord for woods-run logs, 6 inches and over in diameter, to a high of 32 dollars a cord for selected logs, 8 inches and over in diameter intended for special uses, such as match stock and cooperage. The lowest purchase price for air-seasoned, No. 4 Common and Better, 4/4 lumber was 28 dollars a thousand, while the average prevailing prices ranged from 35 to 42 dollars a thousand. Correspondingly higher prices were paid for selected and kiln-dried lumber.

Yield of dimension stock. Yield of usable dimension stock varies with the quality of lumber or plank, the quality of dimension desired, and the size of cuttings. A box and crate concern, utilizing No. 4 Common and Better lumber, reports waste totaling only 10 percent of lumber. In this plant the short ends and trimmings are saved and cut into packing blocks, down to $3\frac{1}{2}$ inches in length. More commonly residue in box and crating manufacture ranges from 20 to 30 percent of the lumber used.

There is also considerable variation in the amount of usable cuttings in the manufacture of core stock. While one plant uses only No. 1 Common and Better lumber, and reports 60 percent yield in usable cuttings from the higher grades of lumber, another manufacturer utilizes No. 4 Common and Better grades, and reports recovery in excess of 65 percent in usable material. A shoe manufacturer obtains an average yield of 2 pairs of wedgie heels from one board foot, surface measure of lumber. The yield of acceptable turning squares ranges from 300 to 400 board feet of squares per cord of 52-inch aspen.

The estimated yield of squares from No. 1 Common and Better lumber ranges from 45 to a maximum of 60 percent of squares suitable for turning. If lower grades of lumber are also included, a yield of 40 percent or less is obtained.

Machining Characteristics and Related Physical Properties of Aspen (4, 6)

Machining, as applied to production of dimension material, refers principally to sawing, planing and resawing of the wood. Since, however, certain classes of dimension stock, such as core stock or furniture parts, undergo further remanufacture, machining of dimension may also include jointing, shaping, mortising, turning, and sanding. Other physical properties of a wood that have direct bearing on its suitability for manufacture and use as dimension stock are gluing and finishing characteristics, its ability to hold fasteners, and its general stability as determined by the amount of

shrinkage and tendency to warp. The relative hardness of the wood may also be very important in such uses as furniture parts.

Weight and hardness. Aspen is one of the lighter and softer of the native hardwoods. When thoroughly air-seasoned its weight is about 27 pounds per cubic foot, or 1,800 pounds per thousand board feet of 4/4, surfaced lumber. The light weight of aspen is an asset for such uses as containers, core stock and turned articles, because of ease of handling and the reduction in cost of transportation.

Aspen is soft and uniform in texture. It meets the requirements for a combination of softness and uniformity of texture about as well as yellow poplar and basswood. This makes aspen suitable for such uses as drawing boards, matches, and certain turned items where softness is a desirable quality. On the other hand, the softness of aspen accounts for difficulties encountered in planing and sanding, and particularly in turning and shaping of this wood. The softness of aspen also restricts its use in furniture to parts not subjected to hard usage or in which good screw-holding power is not required.

Dimensional changes. Aspen shrinks and swells little in comparison with other light hardwoods. This means that many troubles associated with changes in dimension, due to changes in atmospheric conditions, are minimized in the case of aspen products. The small shrinkage of aspen recommends it highly for interior trim, doors, windows, staves, furniture stock, and similar uses, where stability of wood is of paramount importance.

No reliable information is available on the comparative warping tendencies of aspen. It is believed, however, that since it is a relatively straight-grained wood and its shrinkage is low, aspen may be classed among woods of moderate warping tendencies. Much of the reported trouble with warping of aspen encountered in service is undoubtedly due to the use of improperly seasoned stock.

Nailing and screw-holding characteristics. Aspen is classed among the best native hardwoods from the standpoint of freedom from splitting by nails and screws. It is, however, low in ability to hold such fasteners In this respect aspen is about the same as basswood but is poorer than white pine or yellow poplar. A tendency of fasteners, such as small screws, to pull out of aspen core stock is a frequent complaint. Whenever possible larger screws and nails should be used to obtain the required holding power. Because of the softness and uniformity of texture of aspen wood, this can be done in most cases without danger of splitting.

Finishing. The experience of industrial users indicates that aspen takes stain readily. When used in combination with other woods aspen, because of its relative open-porousness, tends to take up stain faster and deeper than closer-textured woods. Therefore, if the same overall technique of staining is employed, pieces made of aspen tend to stain darker. Occasionally the staining of aspen is spotty because the penetrability of aspen is not uniform.

The appearance of finish coats of enamel and paint, and particularly of varnish, lacquer or wax, is affected to a large degree by the smoothness of the underlying surface. In other words, the smoothness and the appearance of the finished surface is dependent on how smoothly the wood surface was planed or sanded prior to the application of finishing materials. Whenever smooth aspen stock is obtained, this wood presents considerable possibilities for natural finish because of the prevalence of a creamy-colored, satiny, figure, reminiscent of true satin wood. In such products as interior paneling and trim, the darker and irregularly colored heartwood does not detract, but on the contrary enhances the overall pleasing appearance of this wood.

Relatively little information is available on the painting and enameling characteristics of aspen. It appears, however, that aspen may be classed among the hardwoods that take and retain such finishes well. The smoothness of the surface, particularly when enameled, depends on the care with which the surface has been prepared for the finish.

Machining of aspen. Aspen is classed among the hardwoods easy to machine, from the standpoint of low-power consumption and dulling effect on cutting tools. On the other hand, it is more difficult with usual production methods to obtain smooth surfaces on aspen than on harder woods. The surface thus obtained is entirely satisfactory for such rougher uses as containers. With some care, satisfactorily machined surfaces can also be obtained for more exacting uses such as core stock or certain classes of turnings. For precision work, however, such as furniture or better quality turnings, aspen is rated only as fair to poor. It has been suggested, however, that the unsatisfactory machining performance of aspen can also be attributed to the common practice of machining this wood with equipment built and set for working other woods. This suggests the desirability of further study of machining characteristics of aspen, with a view to developing special machines and production methods specifically designed for this wood.

(1) Planing. Planing is one of the most important operations in the production of core stock and other finished items. In planing properties aspen is considered poor and is classed with such woods as soft elm, sycamore, and cottonwood. The most common defects developed in planing aspen are fuzzy and chipped grain. These defects, however, can be substantially reduced by drying lumber to 12 percent or less of moisture before planing, and by use of sharp planing knives, placed at the correct angle (about 30°). Some fuzzy grain can also be eliminated by feeding the lumber, whenever practical, so that the cutterhead will revolve with the grain. It was also found that the extent of chipped grain in planing aspen depends on the number of knife cuts per inch; experimentally the best results were obtained with 13 to 22 cuts per inch.

(2) Shaping and turning. In shaping and turning characteristics aspen is considered to be among the poorest hardwoods. Limited experiments, conducted at the Forest Products Laboratory and at Michigan State

College, indicate that there is no satisfactory way of producing shaped or turned cuts of smoothness comparable to better shaping woods, for instance hard maple, birch, or beech. This information corresponds with the opinion prevailing in the industry. Again, it is quite possible that much better results could be obtained with equipment especially designed for aspen.

The inferior shaping and turning characteristics of aspen do not preclude its use for items not requiring very exact and complicated detail. Aspen is used commercially for a number of small variety-lathe items, as well as for special items turned on profile and special lathes. In the opinion of the producers better variety turnings can be obtained from stock dried to a moisture content of 12 percent or less than from greener material. This corresponds with the experimental data already mentioned. Turnings of acceptable smoothness, however, can also be obtained in a properly tooled profile lathe, from green wood.

(3) Sanding. Sanding of aspen is of particular importance because of the prevalence of fuzzy grain in planing, and because of the roughness of shaped and turned surfaces. Because of its softness aspen tends to show scratches and is classed as a difficult wood to sand. The use of coarser abrasives may accentuate fuzziness instead of removing it. Fuzziness in aspen may also develop as a result of sanding against the grain. When properly done, surfaces of satisfactory smoothness can be produced, but considerable attention to detail of sanding and longer time are required than in the case of harder and closer-textured woods.

USE OF ASPEN DIMENSION STOCK

Boxes, Crates and Crate-bases, and Core Stock

At the present time the major uses of aspen dimension stock are in the boxing and crating industry and for manufacture of core stock. These uses are discussed in detail in other aspen reports (8, 12). Very close utilization of aspen lumber is possible in either case.

Aspen is used for reinforcement of cardboard boxes in shipping heavy items and for supporting frames for innerspring mattresses. Considerable quantities of aspen dimension stock are also used for shipping crate-bases, for such items as refrigerators, stoves, and radios. The plywood or corrugated type of box fitted over the item is nailed to the base.

Pallets

There is considerable divergence of opinion among producers and consumers on the merits of aspen in pallet construction. The objections to the use of aspen in pallets arises from its relatively low strength properties and poor nail-holding capacity. In fact, however, except in stiffness, aspen is equal or superior to other lighter hardwoods and such softwoods as jack and white pine. Its low nail-, screw-, and bolt-holding power can be overcome to a large extent by increasing the size of such

fasteners. When properly constructed, aspen pallets should, therefore, be satisfactory for any but very heavy use. To produce the most efficient pallet, it must be designed specifically for the item it is to handle, as well as for the equipment which will be used in moving it.

In construction of pallets either green or air-seasoned lumber is used, depending on the requirements of the consumers. Some manufacturers use aspen only for pallet decking, with the stringers of a heavier hardwood, such as maple, beech, or elm; this is done to obtain a more securely nailed pallet. Other producers reverse the order and use aspen only for stringers, with decking constructed of a heavier hardwood; this results in a pallet with a stronger decking, while at the same time advantage is taken of easier nailing into aspen. Many instances of all-aspen pallets have also been found, especially for uses where strength requirements are not excessive.

Interior Finish

Although not made in large quantities, many examples of the use of aspen in attractive flooring, paneling, matched ceilings, wainscoting, and trim in dwellings and in business establishments may be found throughout the northern Lake States. At present these items appear to be made only on a custom basis, or experimentally.

No special problems in the manufacture of any of these products have been reported. In all instances lumber properly kiln-dried to about 8 to 10 percent is required for satisfactory service. High grade flooring is the most difficult item to produce in quantity because of the low yield of clear cuttings of sufficient length.

The other interior finish products can admit more defects, especially knots, and therefore, can be made of No. 3 Common and Better grades of aspen. The most serious objections to aspen in the manufacture of these products is the prevalence of collapse in the lower grades of lumber. It has been suggested that because of this the lower grades of lumber should be sawed extra heavy, to allow for planing out of the collapsed areas. Unless perfectly smooth paneling is desired, slight collapse does not appear to be very objectionable. In fact, by imparting a somewhat weather-beaten appearance to the paneling, it may appeal to the persons desiring a rustic effect.

No adequate service reports are available to indicate the wearing qualities of aspen flooring. Several instances are, however, on record of aspen flooring giving satisfactory service in such public places as offices, restaurants, and saloons. A very attractive natural finish can be obtained in paneling and trim, whenever proper attention has been given to surfacing of the stock.

It appears that the major problem with large scale production of well-made aspen interior finish is not that of manufacturing, but of

merchandising. The product should not be offered to the consumers under the greatly misused name of "popple." More attractive names such as aspen, Michigan, Wisconsin, or Minnesota aspen, silver aspen, etc., may create more interest in and respect for the product. A promotional program, pamphlets and advertising in trade and professional periodicals, as well as exhibits of finished items, designed to draw the consumers' attention to the decorative possibilities of aspen, should do much to bring about a wider acceptance of this wood for interior decoration.

Furniture

In addition to core stock, quantities of aspen are used for frames in upholstered furniture and for drawer bottoms, mirror, and cabinet backing and for similar other uses in concealed places, or where a low density wood of uniform texture is desirable.

Aspen is used in the smaller shops for juvenile furniture, what-nots, small bookcases, and unfinished furniture. In general the use of aspen is considered a poor risk whenever the article is to be subjected to hard usage. Other objections to the use of this wood in furniture are low recovery of high grade material, inability to obtain a smooth surface with the standard planing and sanding methods, and low nail- and screw-holding capacity.

Of these objections the most valid is the low recovery of high-grade material. A manufacturer using aspen lumber cannot expect to obtain paying quantities of acceptable clear cuttings from No. 2 and No. 3 Common grades of kiln-dried aspen lumber, because of the prevalence of collapse, shake, and numerous small knots. Since most aspen lumber is bought on a mill-run basis large quantities of low grade aspen, unsuited for conversion into furniture stock, will tend to accumulate at the plant. Such material is difficult to dispose of, except when converted into boxes and crates at the same plant.

Aside from core stock the custom manufacture of cut-up stock from aspen for the furniture trade and other more refined uses does not appear to be economically feasible at the present time. The main reasons for this are: (1) the generally unstable conditions in the hardwood small dimension trade; (2) severe competition from already established dimension plants, particularly those operating in the south; (3) competition from the better grade hardwoods, such as maple, birch, and red gum, which are available in large quantities and possess more desirable characteristics for furniture manufacture; (4) limited usefulness of aspen in better grades of furniture, because of the working and finishing properties of the wood; (5) small size and poor quality of aspen logs, with the resulting low yield of higher grades of lumber; (6) abundance of defects in Common grades that largely preclude the possibility of remanufacturing the lower grades of aspen into dimension; (7) inability of manufacturers to produce aspen dimension stock on schedule or in sufficient volume to satisfy customers' needs.

Turning Squares

As was previously indicated, aspen is classed among the poorer turning woods. Nevertheless, quantities of aspen squares are used in production of less exacting turnings. Among these are variety and special lathe turnings, not requiring a very smooth finish. Examples of such turnings are: parts for railroad flares, cores for oil filters, paper plugs, lower grade handles, and clothes pins.

Most of these articles are turned from stock dried to less than 15 percent of moisture. Generally no attempt is made to find out the exact moisture content most suitable for turning a given item. The stock is considered suitably dry whenever articles of sufficient smoothness are obtained. Some types of turnings are produced from green material. For instance, aspen fish net floats are turned green and then dried in revolving, steam-heated drums. To retain a perfectly round shape, paper plugs, ranging from $2\frac{1}{2}$ to 5 inches in diameter, should be turned twice, first green to a size sufficient to allow trueing up, and later, after drying to about 15 percent, to the final, required size.

In spite of poor shaping characteristics aspen is used in the manufacture of wedgie shoe heels and in shaped flat toys. Appreciable quantities of 4/4 to 8/4 better grade aspen lumber are used for wedgie shoe heels by a mid-western and by a southern manufacturer; the latter prefers aspen to southern hardwoods and pine because of its higher resistance to splitting. An average yield of 2 pairs of acceptable heels is reported from one board foot of lumber, surface measure.

Snow Fences and Corn Crib Slats

Aspen is used along with other woods, in the production of snow fence lath. A yield of 1,800 pieces per cord of 4-foot, woods-run aspen bolts is reported; of these two-thirds are of first grade. Some of the poorer material and shorter pieces unsuited for lath are converted into grading stakes. The bolts are sawed into planks, which are ripped into squares. The squares are put through a multiple circular resaw, capable of producing 4 laths at a time. The lath is rough-graded and wired into bundles of convenient size. The wiring of lath into fencing is done as a separate operation. The same lath is also used extensively for corn cribs.

Miscellaneous Uses of Aspen Small Dimension

Aspen has been successfully used for drawing boards, for which purpose its softness and uniformity of texture recommend it as highly as basswood. It can also be used, along with basswood, in the manufacture of candy trays and novelties, items which either allow a certain number of knots and non-rot discolorations or can utilize numerous short cuttings of clear material.

Aspen can be used in agricultural implements, for instance in combines, where woods with fair wearing characteristics are required. At present cottonwood is a favored wood, but since in wearing characteristics aspen is equal or superior to that wood, it should be fully acceptable if a supply of well manufactured lumber of good quality could be assured. Other potential outlets of a similar nature are in the manufacture of laundry appliances, for instance clothes driers and curtain stretchers, and luggage and instrument cases, in place of basswood.

The use of aspen in Venetian blinds and rolls has not proven successful. The objections to this wood in these instances are in the cost of obtaining clear cuttings of sufficient lengths, and the difficulties experienced in obtaining smooth surfaces suitable for enamel finish. In Venetian blinds small knots, common in aspen, are particularly objectionable, because they show readily in the finished product.

During the war some aspen was sold to a piano manufacturer for piano keys, to replace basswood. No objections were voiced to the working qualities of aspen for this purpose. The manufacturer, however, went back to basswood as soon as that wood became available again in sufficient quantities, because of the more dependable supply and greater familiarity with the working characteristics of this species.

No instance of the use of aspen for apiary supplies has been found. Again, the objections to aspen seem to be not the working characteristics of the wood, but the problems connected with procuring aspen lumber of high enough grade to make the operations as profitable as those based on basswood.

MISCELLANEOUS INDUSTRIAL USES OF ASPEN

Grain and Coal Doors

A good outlet for the lower common grades of aspen lumber is in the manufacture of grain and coal doors. These doors are 6 to 7 feet long and are made of a single thickness of lumber for coal and of double thickness for grain doors. Better workmanship and "grain-tight" lumber are required for grain doors. No. 3 and No. 4 Common grades can be used.

Cooperage

Satisfactory tight cooperage for small barrels for pickles, fish, and similar products can be made of aspen. For this purpose only the better grade of logs should be selected, to guarantee a reasonable yield of usable staves. The staves are said to be of good quality, though some fuzzing has been experienced in sawing logs of high moisture content. An important objection to the use of aspen staves is their relatively narrow width, requiring a larger number of staves per container than is the case of staves made of other woods. The problem of procuring aspen logs of uniformly good quality constitutes probably the greatest simple deterrent to the wider acceptance of aspen for this purpose.

Blocking Wedges

Aspen is used for blocking wedges for rail and truck shipping of heavy items. These wedges are made from 4/4 to 8/4 material and are nailed together either in a V or A-shape.

"Iron Sponge"

Another use for low grade aspen in the form of bolts is in the manufacture of "iron sponge," thin wood strands coated with iron oxide and used for the purification of gas. Bolts down to 3 inches in diameter can be used; 4- and 5-inch bolts are preferred.

In this operation the bolts, with the bark on, are chipped in a specially designed chipper across the grain. The resulting strands of wood are about 1 inch wide and 1/16 inch thick. Quality of the wood is not very important and therefore there is a real opportunity for utilization of the poorer grades of aspen bolts, unsuited for more exacting purposes.

SUMMARY

Utilization of aspen for dimension stock is restricted by the working and finishing characteristics of the wood, small size of logs and the low yield of high grade cuttings from the unsorted aspen lumber.

Under the prevailing economic conditions, utilization of aspen for dimension stock is confined largely to its use in containers, core stock, certain rough industrial items, and, to a limited extent, to turning stock.

Aspen is in a poor competitive position with the better hardwoods, in so far as furniture and other more refined uses are concerned; this is due to its less desirable working and finishing characteristics, prevalence of kiln-drying defects and low yield of high grade material. Inability of producers to supply large volumes of high grade material on a study consignment basis is also believed to be an important factor warring against wider acceptance of aspen by wood-using industries.

More extensive utilization of aspen appears feasible in interior finish and for such industrial uses as agricultural implements, drawing boards, luggage, laundry supplies, and other similar uses, particularly where basswood and cottonwood are recognized as standard woods. To achieve wider acceptance of aspen by the manufacturers and consumers it is necessary to give more attention to a dependable supply of well manufactured and graded aspen lumber. A sensible promotional campaign, stressing the desirable characteristics of aspen for interior finish, may be necessary to arouse consumer interest in the possibilities of this wood.

LITERATURE

(1) Benson, A. O.
1931. Manufacture of Dimension Stock from Northern Hardwoods. U. S. Department of Agriculture Circular No. 163. 62 pp., illus.

(2) _____
1936. Dimension-Stock Methods for New England Hardwoods. U. S. Department of Agriculture Circular No. 394. 61 pp., illus.

(3) Clausen, V. H.; Rees, L. W.; and Kaufert, F. H.
1949. Development of Collapse in Aspen Lumber. Forest Products Research Society. Proceedings, Vol. 3.

(4) Davis, E. M.
1947. Machining and Related Properties of Aspen. Lake States Aspen Report No. 8.

(5) Hoyle, R. J.
1931, revised. The Manufacture and Use of Small Dimension. The New York State College Forestry, Tech. Publ. No. 20, 102 pp., illus.

(6) Johnson, R. P. A.
1947. Mechanical Properties of Aspen. Lake States Aspen Report No. 7.

(7) Rees, L. W.
1947. Aspen Lumber for Building Purposes. Lake States Aspen Report No. 9.

(8) Sands, W. M.
1947. Aspen for Containers. Lake States Aspen Report No. 10.

(9) Sands, W. M. and Malcolm, F. B.
1949. Cut-Stock Possibilities in Wood-Consuming Industries. Wood Working Digest. Vol. 51, No. 7, No. 8, and No. 9.

(10) Smith, H. H.
1947. Seasoning of Aspen. Lake States Aspen Report No. 5.

(11) Telford, C. J. and Malcolm, F. B.
1947. Milling of Aspen into Lumber. Lake States Aspen Report No. 4.

(12) Toole, A. W.
1947. Aspen for Core Stock. Lake States Aspen Report No. 11.

(13) Zasada, Z. A.
1948. Aspen Lumber Grades and Characteristics. Lake States Aspen Report No. 6.

LAKE STATES ASPEN REPORT NO. 13

ASPEN FOR VENEER

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PROCESSED BY
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

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FOREWORD

During and since World War II, there has been increasing interest in aspen (Populus tremuloides) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up-to-date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

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18	Chemical Utilization of Aspen
19	Preservative Treatment of Aspen
20	Marketing of Aspen
21	Possibilities of Managing Aspen
22	Enemies of Aspen

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AGRICULTURE - MADISON

REPORT NO. 13

ASPEN FOR VENEER

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INTRODUCTION

In considering possible uses for the large supply of aspen in the Lake States, veneer and plywood manufacture should not be overlooked. Although aspen is not currently in great demand as a veneer species, the reason is not because of technical deficiencies of the wood for this purpose, but rather because there is no appreciable veneer industry in the region adapted for using aspen as small logs, the form in which it is most available.

The technical properties of aspen make it especially well suited for many veneer products. These properties are quite similar to those of basswood and cottonwood, both of which are in demand in log sizes suited to conventional veneer equipment. Such equipment in the Lake States consists of rotary veneer lathes on which it is not economical to handle logs less than about 12 inches in diameter. The minimum diameter for most aspen logs would be about 8 inches.

The technical problems of producing and using veneer from small logs are not difficult to overcome and, in fact, have been worked out in practice. Because of the ease with which it can be cut, its excellent properties as a veneer wood, and its availability, the possibilities for increased veneering of aspen in this region appear excellent.

PROPERTIES OF ASPEN AFFECTING VENEER USE

One of the most important properties of aspen from the standpoint of its use for veneer and plywood is its uniformity of structure. Aspen is technically classed as a diffuse porous hardwood. This means that the grain is generally not distinct. The annual rings do not form bands of hard and soft tissue as found in ring porous hardwoods like oak and in coniferous woods like yellow pine and Douglas fir. Uniformity of wood structure is important in making thin veneer sheets, as it controls uniformity of physical properties. This is particularly true in rotary cut veneer, where the cutting more or less parallels the annual rings. In woods with pronounced ring structure, thin sheets of veneer show variations in density as the knife passes from summer wood (dense zone of the annual ring) to spring wood (less dense part of the annual ring). This variation in density in the sheet of veneer produces variations in strength and shrinkage which detract from the structural value and stability of both veneer and plywood. Lack of uniform shrinkage causes distortion of veneer and plywood sheets with changes in atmospheric humidity and wood moisture content. Aspen has uniform wood structure common to such valued veneer woods as birch, maple, basswood, walnut, and mahogany.

Aspen is a wood of low density. This is an advantage in core veneer for plywood panels. Since the bending strength of a plywood panel depends primarily upon the strength of the surface plies, the core plies, for most uses, need not be as dense and strong as the surface plies. Where light weight is important in plywood, extremely low density materials (sandwich construction) are suitable for cores. In thin plywood panels, cores of comparatively low density and strength are advantageous in maintaining stability. Due to changes in humidity, plywood made of cross-banded structure develops internal shrinkage stresses which may distort the panel. A low density core tends to minimize these stresses. Basswood has long been valued as a core veneer, and aspen has similar properties, with the added advantage of superiority in shrinkage characteristics.

Low density gives aspen an advantage in use as shipping container veneer and plywood. It has high resistance to splitting in nailing and is tough for its weight. In actual tests of boxes, aspen has been found to compare favorably with ponderosa pine in resistance to breakage (6). 1/ In addition, it has light color and lack of odor which are desirable in container wood.

There need be no apprehension about the cutting characteristics of aspen. It is reported to be very similar to basswood in rotary cutting. It can be cut successfully without heating the bolts. Experimental cutting of aspen on a high-speed slicer also has been very successful.

The gluing properties of aspen are excellent. It is classed with those woods "that glue easily with different glues under a wide range of gluing conditions" (7). This makes it well adapted to edge gluing and end joining. Thin panels of veneer or plywood may be readily glued to cleats or framing members.

Aspen is superior to most other veneer woods in paint and enamel holding (5) and is well adapted to surface plies where opaque finishes are required. Its light color and lack of grain allow it to take white and tints with ease. There is no danger of raised grain showing through or of pitch troubles.

The uniformity of grain makes this wood particularly adaptable for plywood uses where uniform wear is required. It wears smoothly without splintering.

Not the least advantage of aspen for veneer is its abundance (8). While old-growth timber, upon which the Lake States veneer industry is based, is rapidly being depleted, aspen is growing faster than it is being cut. It is cheaper than competing woods as raw material. Whether it is cheaper in the finished product depends upon the use of veneering equipment adaptable to small logs and the mechanization of handling small veneer sheets.

1/ Underlined numbers in parenthesis refer to literature cited at the end of this report.

As usual with second-growth timber, aspen is relatively high in defects. To be successful, use of this species for veneer should embrace both high and low grade uses, such as for container veneer and cabinet veneers.

PRESENT USE OF ASPEN FOR VENEER

Aspen is used by several cabinet veneer plants in the Lake States when it can be obtained in sizes suitable for their equipment. The volume used is small because large aspen bolts are scarce in the areas where veneer log buyers are active.

Although aspen can be substituted for basswood, mostly for core and crossband veneer, it brings a lower price. A current offer for aspen veneer logs is $65 per M bd.ft. Predominantly a second-growth tree in the Lake States, its logs generally have more knots below a clear surface than do those of old-growth basswood. Undoubtedly if aspen logs over 12 inches in diameter were common, the species would be more widely used by hardwood veneer and plywood plants.

There are a number of plants manufacturing baskets, boxes, and crates from veneer or plywood in the Lake States, but few are equipped to use small logs. Thus aspen veneer is rarely used in these industries. A notable exception is a plant in an area where aspen attains fair size. Specializing in egg crates, this plant prefers aspen for side and bottom slats. A small agricultural crate plant was found slicing narrow crate slats of aspen on a barrel stave machine. A few other occasional uses of aspen veneer for containers have been reported. Although aspen is a good container wood and is used extensively for the lumber parts of veneer containers, it is not widely used as veneer by the container veneer industry. As in the cabinet veneer industry, this is due to lack of equipment to cut small logs.

The only plant in the Lake States using aspen veneer in large volume is engaged in the production of matches. This plant is equipped with special small-log lathes and uses about 7 million bd.ft. log scale per year in aspen bolts to an 8-inch minimum diameter. Besides being able to turn to a 3½-inch core, the lathes are semiautomatic in operation and are adapted to high speed production.

The green bolts are cut without steaming, although in winter they are stored in a room to remove frost. The standard-length bolts are first conveyed to roughing lathes. They drop between the chucks on an automatic centering device. The chucks clamp the bolt, and the bark and irregularities are peeled off. As soon as the bolt is perfectly rounded across the length, the lathe stops and the chucks open automatically, dropping the bolt to a conveyor. At the veneering lathe the bolts roll into an automatic centering device, and turning continues to a 3½-inch core when the lathe stops and the chucks open automatically.

For this particular use, the veneer is cut into narrow sheets by rotary knives attached to the lathe. These sheets are then reduced to square match sticks by a continuous slicing process. The original veneer sheet, however, has the same characteristics as any rotary cut veneer except that the radius of curvature is less than in large-log operations. This results in a somewhat more open "loose face," but the degree of openness is not visually discernible, even at the $3\frac{1}{2}$-inch diameter. For many uses this would have little technical significance.

METHODS OF CUTTING

Rotary Cutting

Rotary cutting aspen in volume requires special small-log equipment. Lathes capable of turning to a core diameter of 3 inches should be adaptable to cutting bolts as small as 8 inches in diameter. There is an abundance of bolt material in some Lake States areas which satisfies this diameter limitation. The small lathe alone might not make the veneering of aspen economically feasible, but it should be supplemented with equipment for mechanized handling of bolts and the veneer. Further, a market or use would have to be developed for relatively narrow sheets since the diameter of the core limits the bolt lengths. At small diameters a long bolt does not rotate steadily enough for uniform cutting. As with other second-growth timber, it may be expected that aspen bolts would develop a relatively high percentage of veneer with tight knots near the core. For much of the material it might not be feasible to clip out defects as is done in conventional hardwood veneer manufacture. For an economical operation, markets or uses would be needed for all grades of veneer.

Small-log lathes are common in Scandinavian countries, where wood-using industries are based entirely upon second-growth timber (figure 1). An example of such large-scale use is in the manufacture of hardwood plywood tea chests in Finland for export. It is reported to be common practice in Finland to veneer 6-inch bolts to a core diameter of 3 inches (9). In Sweden, birch bolts of 23 to 25 centimeters (9 to 10 inches) are turned to core diameters of about 5 centimeters (2 inches) (10).

Small-log lathes are used to some extent in the South and the West in this country. The installations are usually small, involving homemade or custom-built lathes, to manufacture veneer agricultural box shook. A common method is to cut the bolts the length of the container slat required. The sheets are then fed into a fixed-interval clipper which makes the slats. Another method of producing shook is to use a "back roll" at the lathe to cut into the surface of the bolt at fixed intervals. The slats are then sorted by grade according to defect.

Slicing

Slicers for high-speed production have been developed in the West. These are not to be confused with slicers commonly used in Lake States veneer

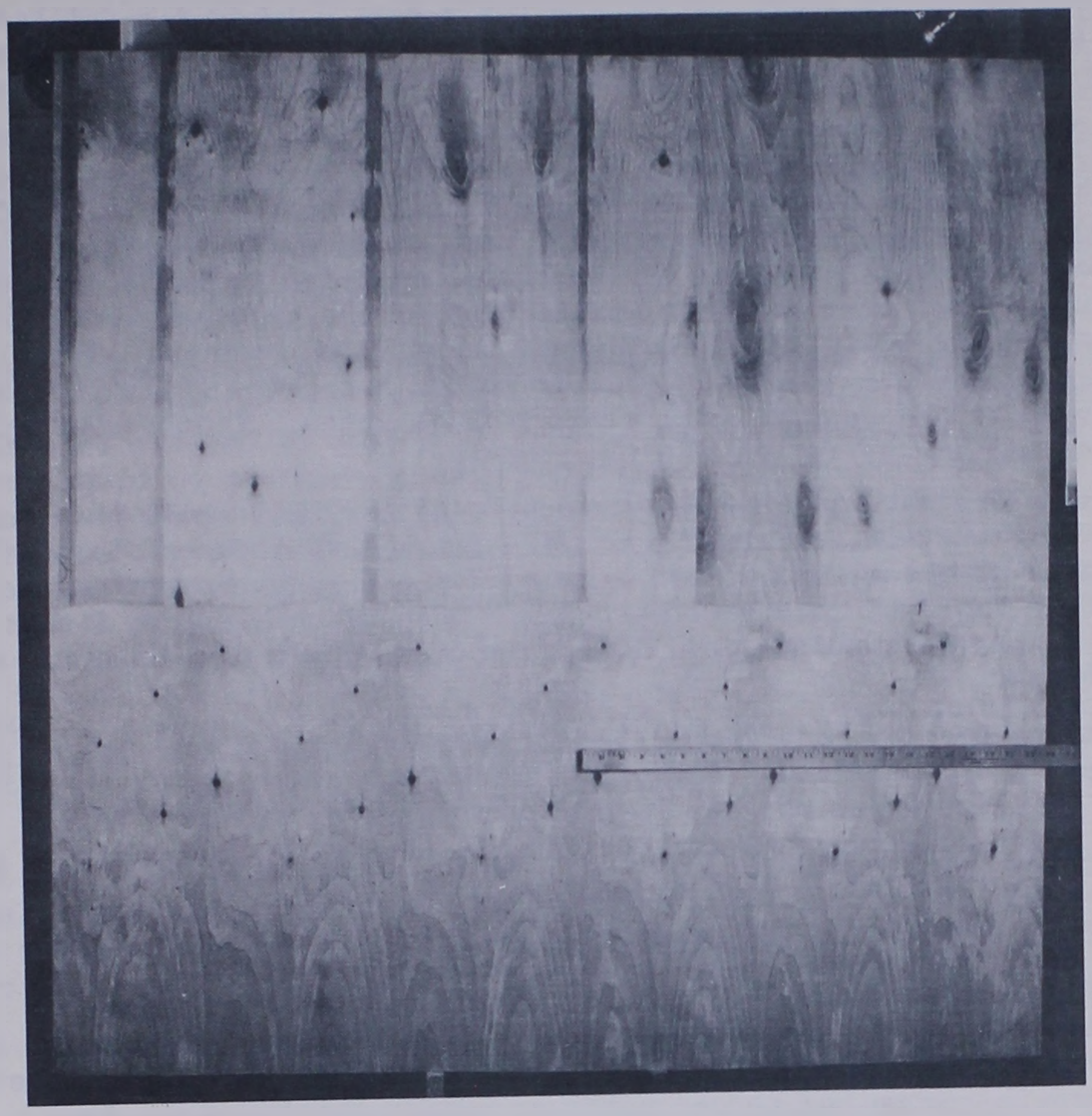

Figure 1. --Sheet of 4' x 4' x 1/8", 3-ply birch plywood made in Finland and retailed in northern Michigan. Note the minimum distance between knots is 8-1/4" indicating a bolt diameter of 2-5/8" at that point. Also note scarf joint, and edge joining of narrow veneer sheets. This size sheet retails currently at 16 cents per square foot.

mills for cutting fancy flitches. They were developed for the production of battery separators and box shook. Sawn blocks are fed continuously into a reciprocating knife, producing slats according to the depth and length of the blocks. One standard model can be supplied with a maximum opening of 36 by 9 inches, although larger sizes could be constructed.

Small logs would limit the size of veneer strip produced, but with careful sawing, blocks could be prepared with less total waste than entailed in sawing lumber. This waste would be minimized if narrow strips could be utilized. Although these machines are now designed for squared blocks, it is possible that a dogging device for round bolts could be devised. This would afford more complete utilization of the bolt and would produce strips of random width which would need to be edged jointed. The slicing method could produce veneer of greater length along the grain than is possible in rotary cutting with a small-chuck lathe. Thicknesses up to 5/16 inch may be cut in the slicing process.

Sliced veneer apparently has more strength as a single sheet than rotary veneer. One western box shook specification allows thinner slats if sliced than if rotary cut. For example, 4-slat orange covers may be supplied in 1/7-inch rotary veneer or 1/8-inch sliced veneer; 2-slat lug covers may be supplied in 1/10-inch rotary veneer or 1/14-inch sliced veneer.

Aspen strips made by this method should be sorted for grade and put to their most profitable use. Some salvage of cull pieces could be accomplished by clipping to shorter lengths and narrower widths. In one western plant this function has been highly mechanized by combining a clipper with multiple trimmer saws (1).

MANUFACTURING METHODS

The objection that aspen logs produce only small clear cuttings of veneer is less valid today than formerly, since efficient equipment has been developed for building small sheets and strips into larger sheets. As old-growth timber has become scarcer, veneer manufacturers have accepted smaller and more defective logs. This has reduced the average size of veneer cutting and has increased the handling cost for large veneer sheets and plywood panels. Even face veneer is commonly made up of several joined pieces. Equipment for joining veneer strips into sheets with a minimum of manual labor is being evolved to reduce cost of handling the small cuttings. In the conventional hardwood plywood plants of the Lake States a considerable amount of hand labor is devoted to edge gluing veneer into larger sheets. This expense can be borne by high-value furniture and cabinet woods, but is not economical for aspen with its high proportion of small cuttings.

Successful use of aspen for panel stock would require a continuous process whereby narrow strips are fed on a conveyor, glue applied to the edges, and the joined strips passed through a heating element, emerging as a

continuous sheet. Such machines are in fairly common use (4, 14). Continuously joined sheets of aspen veneer would be as useful for most purposes as solid sheets of basswood. The strips could be cut on either rotary or slicing equipment. There might be an advantage in favor of slicing, as strips of uniform width are well adapted to mechanized handling and glue application.

For core veneers and for general purpose plywood, glue jointing is not always required, and strips may be formed into sheets by taping with kraft gummed paper (figure 1). A continuous automatic machine for this purpose would need to be developed.

We have mentioned methods for overcoming the deficiency of aspen veneer in width of cutting (across the grain). Rotary veneer from small-log lathes is also limited in length of cutting (along the grain). This deficiency could be overcome by end joining the sheets, as shown in figure 1. A simple scarf joint is the usual method, but the cutting and gluing of the joint is a painstaking and time-consuming operation suitable only for high-value veneers and products. A recent German invention might make it feasible to end-scarf short aspen sheets in a continuous operation (11). An auxiliary knife is attached to the lathe at an angle of 1:20 so that it cuts a scarf edge on the veneer sheet as it is peeled from the bolt. Thus the scarf joints are cut automatically. The scarfed sheets could be formed into a sheet of indefinite length along the grain by passage through a high-frequency gluing machine.

Machines are under development for continuous gluing of laminated boards from small cuttings of lumber of uniform width and thickness. Such a process could well be adapted to small veneer cuttings of aspen. This would be particularly true of strips from a high-speed slicer.

SUGGESTED USES FOR ASPEN VENEER

Aspen has high technical qualities in the clear wood, yet it has a relatively high percentage of natural defects even in veneer logs. For this reason utilization should be directed to both clear veneer and low-grade veneer in the same operation. A departure should be made from the usual specialization in veneer production where emphasis is placed upon product rather than on the raw material. Container veneer mills often put a significant proportion of high-value clear veneer into a product that does not require it, whereas a cabinet veneer mill may waste a significant proportion of cuttings that are too defective for finish plywood panels but are suitable for containers or utility plywood. Although specialized plants using old-growth timber are able to control the amount of misused raw material by specifying log grades, it is not known whether aspen logs can be graded effectively for this purpose.

Container Veneer and Plywood

The container field should offer an excellent outlet for aspen veneer. Aspen has properties found in many preferred container woods. For some types of containers its low density might have to be compensated by slightly greater thickness to attain strength equal to competing woods. The production of aspen box slats by the high-speed slicing process should compete successfully in the Lake States with resawn high-cost western lumber.

The toughness and resistance to splitting of aspen should suit it for stitching veneer slats to cleats for container shook. The wirebound box has a wide and growing application in the packaging field, and aspen veneer strips should be suitable for this highly mechanized construction. Cottonwood, a close relative of aspen and quite similar in properties, is in common use as wirebound box slat material. Experimental wirebound boxes made with aspen slats have shown up favorably.

Aspen veneer even in comparatively narrow and short sheets should be well suited for plywood containers of popular size. For many types of plywood container panel, restrictions on defects would not be difficult to meet, and the core and back ply could utilize sound defects. As in other plywood uses, it would be most economical to mechanize the production of large veneer sheets from relatively small strips.

General Purpose Plywood

General purpose plywood might be defined as that where neither the density and finishing characteristics of birch nor the structural strength of Douglas fir is required (figure 1). There are literally hundreds of factory and retail uses for which aspen should be adequate, such as for signs, boatfittings, household cabinets, unpainted casegoods, concrete forms, display fixtures, trailer and bus fittings, ironing boards, lockers, store fixtures, furniture back panels, and luggage. Its moisture stability, smooth texture, and excellent paint and enamel acceptance make it equal or superior to many competing woods. The growing practice of overlaying common grades of plywood with plastic, resin-impregnated paper, or metal sheets (2, 3) would overcome common defects and frequency of veneer joints of aspen plywood.

The western softwoods are firmly established in the general-use market, but that market is still expanding and the freight advantage to large consuming centers seems to offer Lake States aspen an excellent opportunity to compete. Success will depend upon cutting costs of production through mechanization to outweigh the production cost of plywood from large clear veneer sheets from western timber. At present aspen is unknown in the general plywood market and also suffers from an unjustified prejudice. Its introduction into the plywood market will require considerable sales effort, but it should find a place in the market as an adequate but cheaper substitute for the more commonly used plywood species.

Special Use Plywood

Special use aspen plywood should do well in lumber panels where low density hardwoods of uniform structure are required. This is the field in which basswood has long been known as a special use wood. The key uses in this category are drawing boards, bread boxes, paper hangers' boards, and plywood cores. There are numerous manufactured articles for which well manufactured panels of aspen plywood are technically superior to high-density hardwoods or to the characteristically non-uniform-textured softwoods. Clear-faced aspen plywood would be more acceptable than aspen lumber, since high grades of aspen lumber are too uncommon to be widely used for factory purposes. Basswood has long enjoyed a preference as lumber core stock upon which to glue high-quality face veneers. Recently aspen cores have become recognized as having similar desirable properties for this use. Aspen plywood panels should also be well suited for overlaying with fancy face veneers. Crossbanding between surface plies and cores could as well be of aspen as of basswood.

The properties that should be stressed in proposing aspen for special uses are (1) ease of gluing, (2) excellent acceptance and retention of paints and enamels, and (3) smoothness in wearing without splinters. These are characteristics which aspen possesses in common with such commercially favored woods as basswood, white pine, and yellow poplar.

IMPROVED WOODS

Improved woods such as "Impreg" and "Compreg," developed by the Forest Products Laboratory, are most readily processed in the form of veneer, since complete impregnation of solid wood is difficult. The veneer sheets are treated with the appropriate chemical and then combined to form blocks of required thickness. Aspen because of its low density absorbs chemicals more quickly and to a greater degree than denser woods.

The several processes for increasing the moisture stability and hardness of wood by impregnating with resins or resin-forming chemicals are slow in coming into commercial use, mainly because of the high cost of treatment and of the chemicals. So far the method is reserved for articles of high technical requirements and high cost. As methods of production are cheapened and as chemical costs are reduced, these processes should become more widely adopted. An opportunity exists to establish carefully manufactured and graded aspen veneer as a favored raw material for modifying treatments.

One of the advantages of "Compreg" is that it "can be made from soft, inferior species that normally are not used for furniture and a product obtained equal in appearance and in almost all strength properties to "Compreg" made from birch or maple" (12). Aspen actually has some advantages over denser woods in this process. It may be removed from the press hot, thus avoiding a costly cooling period in the press (13).

LITERATURE CITED

(1) Anonymous
1947. Retrieving waste veneer. The Timberman. 48(3): 154, 156.

(2) _____
1948. Paper and plastic overlays. The Timberman 49(3): 65.

(3) _____
1948. Production of "Welchboard." The Timberman 49(3): 68,70, 74, 76.

(4) Arneson, Gus H.
1947. Possible uses of radio frequency heating in the plywood industry. University of Washington, College of Forestry, Bulletin No. 2. pp. 21-23.

(5) Browne, F. L.
1934. Behavior of house paints on different woods. Forest Products Laboratory Report No. R 1053. 19 pp. (mimeo.)

(6) Carlson, T. A.
1929. Suitability of little-used species for containers. Forest Products Laboratory Report No. R 1402. 9 pp. (mimeo.)

(7) Forest Products Laboratory
1940. Wood handbook. U. S. Department of Agriculture Unnumbered Publication. 325 pp.

(8) Lake States Forest Experiment Station
1946. Revised forest statistics for the Lake States, 1945. Station Paper No. 1, Lake States Forest Experiment Station.

(9) Leicester, W. F.
1944. The influence of modern glues on the utilization of wood. Conference Report on New Developments in Wood Products, New York State College of Forestry. pp. 53-63.

(10) McKellar, A. D.
1947. Veneer and plywood industry in Sweden. Industrial Reference Service. Part 6, Forest Products, Vol.5-Part 6, No. 5, pp. 1-4.

(11) Seborg, R. M. and Fleischer, H. O.
1945. Veneer and plywood manufacturing techniques and machinery observed in Western Germany. FIAT Final Report No. 389, Joint Intelligence Objectives Agency.

(12) Stamm, A. J.
1944. Possible use of improved woods and wood-based plastics in the furniture industry. Forest Products Laboratory Report No. R 1482. 4 pp.

(13) _____ and Seborg, R. M.
1941. Resin-treated, laminated compressed wood. Forest Products Laboratory Report No. R 1268. 8 pp.

(14) Wood, A. D. and Linn, T. S.
1943. Plywoods, Chemical Publishing Company. 363 pp.

LAKE STATES ASPEN REPORT NO. 14

ASPEN FOR PULP AND PAPER

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OCTOBER 1947

PROCESSED BY
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (*Populus tremuloides*) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up to date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

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REPORT NO. 14

ASPEN FOR PULP AND PAPER

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Forest Products Laboratory 1/

INTRODUCTION

Although the use of hardwoods for pulp and paper manufacture has increased considerably during recent years in the Lake States, the pulpwood consumed in this region consists largely of softwood species of which about one quarter is obtained from foreign sources. The wood resource, on the other hand, is comprised to a large extent of hardwoods, predominantly aspen, with the maples, oaks, and several other species available in lesser amounts. The present stand of aspen in the Lake States is estimated at nearly 20 million acres with a total volume of merchantable timber of about 32 1/2 million cords. The present use of approximately 440 thousand cords of aspen as pulpwood is relatively small in comparison to the allowable annual drain of over 2 million cords (1, 2).2/ Though the use of softwood pulpwood in the Lake States will undoubtedly continue to be highly important, the potentialities of aspen as pulp and paper-making materials are such that its utilization for these purposes may readily be increased to a volume considerably greater than at present. Such an expanded use, however, would require not only an increase in production by present methods but the development of modified and new processes, modified paper formulas, some new products, and possibly the manufacture of some products not now manufactured extensively in the Lake States. Some of these will be discussed herein.

The statements in this report, though confined to methods applicable to quaking aspen (Populus tremuloides) and the paper products in which this species can be used, may be considered as also applying generally to other Populus species such as big-tooth aspen, eastern cottonwood, balsam poplar, balm-of-Gilead, and others which grow in the Lake States.

CHARACTERISTICS, PREPARATION, AND STORAGE OF ASPEN PULPWOOD

Aspen is a diffuse-porous hardwood of relatively light color and low density. The color of the heartwood varies from grayish white to light grayish brown. The sapwood is slightly lighter colored. The range of density of the aspen used for pulping is from about 20 to 24 pounds per

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1/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Wisconsin, Madison, Wis.
2/ Underscored numbers in parentheses refer to literature cited.

cubic foot (oven-dry weight, green volume), which is low in comparison to many other hardwoods and some softwoods. This fact is important from the standpoint of the yield of pulp that may be obtained per cord of wood, especially as groundwood pulp. In chemical pulping, the relatively low weight of aspen wood per cord is compensated for by a relatively high cellulose content, so that the yield of chemical pulp that can be obtained per cord is nearly comparable to that of some of the softwoods.

The average fiber length of aspen is approximately 1 mm. and the average diameter about 0.03 mm., giving a ratio of length to diameter of 33 to 1. Pulps prepared from aspen also contain smaller fragments of woody tissue. This aggregate of relatively short fibers and cellular matter has a definite influence on the properties of the papers in which the pulp is used as a component. Aspen pulps are generally more suitable for use in papers requiring softness, bulk, opacity, good formation, and good printing qualities than in those requiring toughness, good strength, higher density, and harder surface characteristics.

A typical chemical analysis of aspen is given in table 1.

The pulpwood is usually cut to a 4-inch minimum top diameter in 100-inch lengths. Prior to the war, most aspen pulpwood was peeled in the woods. Wood cut in late summer and winter is more difficult to hand-peel. Winter-cut wood that remains green until spring will become growth active and hand-peel with less difficulty. However, it is necessary that practically all of the winter and spring-cut wood be peeled before the sap between the bark and wood has dried, that is, generally by the middle of July. The scarcity of woods labor during the war compelled most of the mills to accept unpeeled wood. With recent improvements in mechanical and hydraulic barking equipment, the continuation of the barking of hardwoods at some mills can be expected. On the other hand, there has been considerable interest shown recently in the development of a mechanized system of tree-length logging, skidding to a semi-portable mechanical barker, sawing to the desired length, and mechanically loading on trucks or trailers for hauling to mill or rail shipping points (3). Other developments in the mechanization of pulpwood logging in the Lake States are anticipated.

For the mechanical pulping processes, manufacturers prefer to purchase unpeeled aspen pulpwood in the green condition. In these mills the plan is to deliver the wood so that it can be used soon after it is received. When it is necessary to stock-pile aspen, it is stored for only a few months. The manufacturers of chemical pulp prefer to buy peeled wood, since seasoning is desirable for reducing trouble caused by gums and waxes. The average seasoning period for peeled aspen pulpwood is about eight months. If unpeeled aspen is purchased for use in the soda process, a seasoning period of at least one year is necessary. Peeled aspen can be stock-piled for as long as two years without serious losses in pulp yield. If unpeeled wood is stored in piles through a second summer, serious losses in pulp yield can be expected. For stock-piling unpeeled aspen, winter-cut wood is preferred to that cut in summer.

Table 1.--Density, fiber dimensions, and chemical composition of aspen (Populus tremuloides) (typical values)

Density (moisture-free weight and green volume)		lb. per cu. ft.	22
Fiber dimensions:	Length	mm.	1
	Diameter	mm.	0.03
Chemical composition: (based on moisture-free wood)			
Holocellulose:	Total	percent	82
Cross and Bevan cellulose:	Total	do.	64
Alpha cellulose:	Determined on holocellulose	do.	51
	Determined on Cross and Bevan	do.	48
Lignin		do.	17
Total pentosans		do.	23
Solubility in:	Ether	do.	1
	1 percent caustic soda	do.	19
	Hot water	do.	3
Ash		do.	0.3

GROUNDWOOD PULPING

Aspen is suitable for the manufacture of both a coarse grade of groundwood pulp for use in insulating board and finer grades for use in groundwood book and specialty papers and newsprint. Recent experiments at the Forest Products Laboratory indicated that for the production of pulp of the quality used in book paper, duller stone surface conditions are preferable to sharper surfaces from the standpoint of production rate and energy consumption. For the production of pulps with equal properties, it is necessary to use conditions which consume much more energy per ton for grinding aspen than for grinding spruce. When ground under the same conditions, however, aspen pulp has higher freeness and lower strength than spruce pulp (4). Under the same conditions, aspen grinds at a higher rate, and consumes less energy per ton than spruce. The lower strength of the freer aspen groundwood pulp prepared with less energy consumption can be compensated by blending with strong aspen semichemical pulp. Experiments in which the pulp has been utilized in this way are described later. A comparison of aspen and spruce ground under the same conditions is given in table 2.

Table 2.--Comparison of aspen and white spruce groundwood pulps prepared under the same conditions 1/

		Aspen	Spruce
Grinding rate (moisture-free wood per 24 hours 2/	tons	0.96	0.64
Power input 2/	hp.	74	67
Energy consumed per ton moisture-free wood	hp.-days	77	104
Pulp suspension properties:			
Freeness (Canadian Standard)	cc.	113	20
Screen analysis:			
Retained on 24-mesh 3/	Percent	1.2	7.2
Retained between 24- and 80-mesh	do.	36.2	25.5
Retained between 80- and 150-mesh	do.	21.8	21.1
Passing 150-mesh	do.	40.8	46.2
Fiber length index	do.	.096	.089
Pulp test sheet properties: 4/			
Bursting	pts. per lb. per ream	.19	.45
Tearing	gm. per lb. per ream	.44	.72
Tensile	lb. per sq. in.	970	2680

1/ Carborundum pulp grinder stone. Grinding surface burred with a 10-cut, 1 1/2-inch lead spiral burr and a 14-point diamond burr. Surface condition, medium dull. Peripheral speed, 4,185 feet per minute. Pressure, 20 pounds per square inch of wood on stone. Grinder pit temperature, 165° F.: consistency, 3.5 percent.
2/ Per square foot of wood-stone contact area.
3/ Tyler standard mesh.
4/ Basis weight of test sheets, 115 pounds per ream (25 x 40 - 500).

SULFITE PULPING

Aspen is readily digested by the sulfite process. Because of the lower density, the weight of chips charged to a digester tends to be less than that of spruce chips. As mentioned above, however, the yield of pulp from the same weight of wood is higher, because of its higher cellulose content, so that the yield per digester charge or per cord is almost the same. The yield of aspen sulfite pulp can be expected to range normally between 46 and 54 percent by weight or between 720 and 1,170 pounds per standard rough cord. The time for penetration of cooking acid into the aspen chips at 110° C. is about the same as for spruce (5), but the cooking time is shorter because of faster pulping rate and lower initial lignin content (5). The cooking temperature may be reduced as much as 10° C. in comparison with spruce for the same cooking time.

Mixtures of aspen with spruce or balsam have been reported to cook satisfactorily in all proportions (6). Proportions of aspen varying from 10 to 30 percent are used in general practice, but the higher amount is said to give the best balance with regard to pulping time and pulp quality.

The bursting and tearing strengths of aspen sulfite pulp as indicated in table 3 are about 50 and 60 percent, respectively, of those of spruce sulfite pulp. Aspen sulfite pulp is soft and bulky, is easily bleached, and imparts good printing qualities to the book and magazine papers in which it is largely used. Other important uses of aspen sulfite pulp are in writing, mimeograph, toweling, and tissue papers. Small amounts have been used in newsprint. The proportion of aspen pulp used in these papers is variable, depending on the grades manufactured and the quality of the other pulps with which it is mixed.

SEMICHEMICAL PULPING

Tests at the Forest Products Laboratory have shown that aspen, because of its high cellulose and low lignin contents and light color, is especially suited to pulping by the neutral sulfite semichemical process. This process consists of partial chemical digestion of wood chips with a solution of sodium sulfite and sodium bicarbonate, followed by mechanical fiberizing of the softened chips. The yields of pulp obtained are high (70 to 85 percent) compared to those obtained by more complete chemical pulping processes, and the costs of production are low (7). The tearing strength of aspen unbleached neutral sulfite semichemical pulp is shown in table 3 to be higher, on a comparative basis, than aspen pulps prepared by the sulfite, soda, or sulfate processes and the same is indicated for the bursting strength except for that of the sulfate pulp.

Unbleached aspen semichemical pulp is used in the manufacture of insulating board and blanket. Corrugating board of excellent quality has been made experimentally at the Forest Products Laboratory from aspen semichemical pulp. Results of the Laboratory's work also indicate

possibilities of using unbleached aspen semichemical pulp to a considerable extent as a substitute for long-fibered coniferous pulps in liner board, specialty boards, and in combination with groundwood pulp in printing papers.

In spite of its high lignin content, experiments have shown that aspen neutral sulfite semichemical pulp is readily bleached by conventional chlorine processes (8) or with sodium peroxide (9) with yields of 58 to 80 percent (based on oven-dry wood) depending on the degree of bleaching. The bleached semichemical pulp is shown in table 3 to be higher than all the others in both strength properties. It will be observed that the strength of the bleached pulp is comparable to that of unbleached spruce sulfite pulp. Experimental runs at the Forest Products Laboratory followed by mill-scale trials indicated bleached semichemical pulp to be suitable for use in books, glassine, and tissues. In experiments on the making of machine-coated, groundwood-book paper, promising results were obtained by substituting aspen bleached neutral sulfite semichemical pulp for 60 percent of the softwood sulfite pulp used. The groundwood portion (50 percent of the total fiber furnish) consisted of a relatively free, moderate-energy-consumption, aspen pulp thus making a total of 80 percent aspen pulp in the furnish.

Aspen pulped by the acid sulfite semichemical process in the yield range of 55 to 65 percent was found in Forest Products Laboratory experiments to be a fairly satisfactory substitute for part of the spruce sulfite pulp in a creped towel paper.

SODA AND SULFATE PULPING

The largest use of aspen in paper making is in the form of soda pulp. For this purpose, it is digested either alone or in mixtures with other hardwoods. The yield of oven-dry, unbleached pulp obtained will vary within 45 to 50 percent by weight of oven-dry wood or from about 675 to 1,080 pounds per standard rough cord. Soda pulp is practically always bleached. The principal characteristics which this kind of pulp imparts to paper are opacity, bulk, softness, and absorbency. The strength of soda pulp is low in comparison with that of other kinds of pulp, the unbleached pulp varying from about 61 to 42 percent of the various strength properties of unbleached spruce sulfate pulp (5). Its principal use is in combination with bleached sulfite pulp in the manufacture of book paper. Some is used in tissues, particularly facial tissues.

A relatively small amount of aspen is pulped by the sulfate process. Unpeeled aspen can be pulped by this process with very little more chemical than is required for peeled aspen (10). It can be satisfactorily cooked in mixtures with jack pine in quantities up to 25 percent. This mixture has been noted to require approximately 10 percent less chemical than jack pine alone. The qualities reported (10) to be gained by using aspen with jack pine are better formation, a more closed sheet, and improved tearing strength. The mixture also requires less refining.

OTHER PROCESSES AND FIBROUS PRODUCTS

Coarse Fiber

Aspen is suitable for the production of a coarse fiber which is used largely by the roofing felt industry and in lesser amounts in the manufacture of insulating board, paperboard, and molded products. Wood marketed for this purpose is often called "fuzz wood," "fiber wood," or "felt wood" instead of pulpwood. The fiber can be made by the dry shredding of low-grade round wood, slabs, edgings, and other waste at least 2 feet in length. For best results it is said to be desirable that the wood be in a green or moist condition rather than dried out. Coarse fiber for similar purposes can also be made by the presteaming or by the mild chemical treatment of the wood, followed by fiberizing in attrition mills. This can be done continuously in single machines, or the treatment and milling can be done batchwise in separate equipment in a manner similar to the semichemical process described above.

Purified Pulp

Because of its high cellulose content and ease of pulping aspen is an attractive material for the production of purified pulp, also frequently called alpha pulp or "dissolving" pulp. This kind of pulp is used for the production of regenerated cellulose yarns and fabrics, lacquers, plastics, and explosives. Nearly all of the alpha pulp now produced is made from the longer-fibered softwoods. Only a small amount is produced from shorter-fibered hardwoods. It is probable that the increasing demand for alpha pulp will provide the incentive for a more extensive use of hardwoods. When techniques are developed which permit the more general use of shorter-fibered pulps, purified aspen pulp is likely to find ready acceptance. The wood could be digested by the sulfite process or a modified sulfate process and the pulp purified by conventional methods. The digesting of aspen with nitric acid has received considerable attention as a possible method of producing pulp for subsequent purification (11, 12). The possibility of obtaining a high yield of alpha pulp by the purification of neutral sulfite semichemical pulp is a factor favoring the consideration of that process.

Table 3.--Comparison of strength of aspen chemical and neutral sulfite semichemical pulps with that of spruce unbleached sulfite pulp 1/

Kind of aspen pulp	Bursting strength 2/	Tearing strength 2/
	Percent	Percent
Bleached semichemical	110	105
Unbleached semichemical	80	85
Bleached sulfate	80	90
Unbleached sulfate	90	75
Bleached soda	50	60
Unbleached soda	65	75
Unbleached sulfite	50	60

1/ From "Pulping Characteristics of Available Lake States and Northeastern Woods," by J. N. McGovern, E. R. Schafer, and J. S. Martin. TAPPI Monograph Series No. 4: 130-152 (1947). Forest Products Laboratory Report R1675 (1947).
2/ Relative to unbleached spruce sulfite pulp as 100 percent. Strength in the Schopper-Riegler freeness range of 550-600 cc.

LITERATURE CITED

(1) Demmon, E. L.
1947. Available pulp timber stands in the Lake States. Pulpwood Stands, Procurement and Utilization, TAPPI Monograph Series No. 4: 40-51.

(2) Chase, Clarence D.
1947. Aspen availability and supply. Lake States Aspen Report No. 2, Lake States Forest Experiment Station, U. S. Forest Service.

(3) McNutt, J. W.
1947. New developments relating to improved methods of pulpwood procurement in the Lake States. Pulpwood Stands, Procurement and Utilization, TAPPI Monograph Series No. 4: 95-104.

(4) Hyttinen, Axel, Mackin, G. E., and Schafer, E. R.
1947. Grinding quaking aspen for use in printing papers. Forest Products Laboratory Report R1679. Presented at meeting of Technical Association of the Pulp and Paper Industry, February 24-27, New York, New York. Abridged: Paper Industry and Paper World 29 No. 2: 271-274 (May 1947).

(5) McGovern, J. N., Schafer, E. R., and Martin, J. S.
1947. Pulping characteristics of available Lake States and northeastern woods. Pulpwood Stands, Procurement and Utilization, TAPPI Monograph Series No. 4: 130-152. Forest Products Laboratory Report R1675.

(6) Green, H. W., Mitchell, C. R., and Yorston, F. H.
1937. The pulping of hardwoods by the sulfite process. Pulp and Paper Mag. Canada 38, No. 2: 108-115.

(7) McGovern, J. N.
1945. Semichemical pulp. TAPPI Bulletin No. 53. Forest Products Laboratory Report R1477.

(8) Simmonds, F. A., and Kingsbury, R. M.
1947. Bleaching of semichemical pulp. Paper Trade Journal 124, No. 4: 53-60.

(9) Kingsbury, R. M., Simmonds, F. A., Mills, R. T., and Fennall, F. L.
1946. Bleaching aspen neutral sulfite semichemical pulp with sodium peroxide. Paper Trade Journal 123 No. 11: 50-54.

(10) 1945. Paper Mill News 68 No. 26: 12, 14, 25.

(11) Aronovsky, S. I., and Gortner, R. A.
1937. The cooking process, X, pulping with alcoholic nitric acid. Ind. Eng. Chem. 29: 1431-1434.

(12) Reyerson, L. H., and Montonna, R. E.
1941. Alpha pulp from second-growth timber. Chem. Bull. (Chic) 28 No. 9: 265. Bull. Inst. Paper Chem. 12: 120, Canadian patent 398, 573.

LAKE STATES ASPEN REPORT NO. 15

ASPEN FOR CABIN LOGS

BY
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NORTH CENTRAL REGION

SEPTEMBER 1947

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U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

REPORT NO. 15

ASPEN FOR CABIN LOGS

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Milwaukee, Wisconsin

Introduction

A plentiful supply of pine and cedar logs provided the early settlers of this country with a cheap and durable material for the construction of their homes and farm buildings. Only the axe and the ingenuity of the pioneer were needed to erect a shelter against the elements of nature. Early in the 19th century, the circular saw came into use resulting in a change in building construction. The pine stands in New England and in the Lake States, considered inexhaustible in the 19th century, were converted to lumber to construct buildings necessary for the rapid development of the country. Log cabin construction continued on a very small scale but was largely confined to the inaccessible parts of the country where a cheap and plentiful supply of good building logs still existed. Today, with lumber and pulpwood prices the highest in the history of the country, aspen is about the only cheap and plentiful building log material in the northern Lake States.

Extent of Present Use

It is estimated that less than 10% of the log cabins in the Lake States are now constructed of aspen. In localized areas where there is a shortage of pine, spruce and balsam fir, the use of aspen as a cabin log material is increasing. In these areas, up to 25% of the log cabins constructed these past few years have been built with aspen.

Whole log and split log construction of the palisade type is most commonly used. The logs are usually eight feet long, with a minimum top diameter of six inches. Palisade type cabin logs are much easier to obtain than logs of longer length which are usually used in horizontal type construction. Practically any commercial aspen stand over 40 years of age will yield palisade type cabin logs, while only the better stands of mature aspen will yield satisfactory logs for horizontal type construction. The lower cost of logging the shorter lengths is also an item to consider. Short length cabin logs are easy to skid and haul and the logs can be secured from a smaller area than if longer logs are needed.

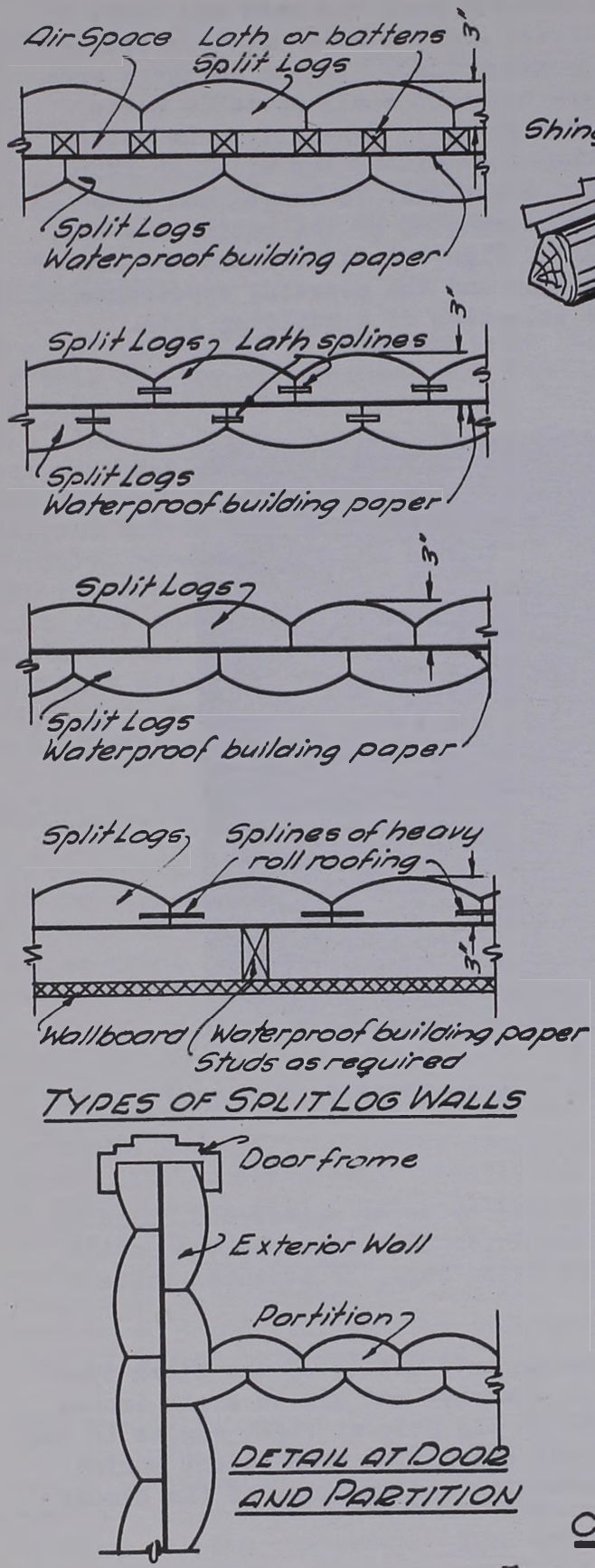
When small size aspen is used in palisade type of construction, whole logs are usually used. The sizes of the pieces vary from five to nine inches in diameter. Two edges of the logs are usually faced to provide for close matching and any cracks are chinked with cement, moss or other chinking material. Sometimes they are set together by use of a spline joint. The interior of the cabin may be left in a natural state if it is designed for summer use.

Split log construction of the palisade type is becoming quite popular in some areas. The quality of the structure and the ease and costs of securing this kind of cabin log material are the major factors responsible for the change from horizontal log construction. In the northern area where log cabins are built, there are numerous small portable mills available for splitting and edging the pieces. Generally, the split log palisade type of construction uses logs with a top diameter above eight inches. The logs are cut about eight feet in length and sawed in half lengthwise and edged. In the construction of the cabin, the half logs are placed upright, edge to edge. Figure 1 illustrates the use of short logs in palisade type construction and the pleasing appearance of the cabin when care is given to the selection of a building site.

Figure 1. The use of short logs in palisade type construction. F-401013

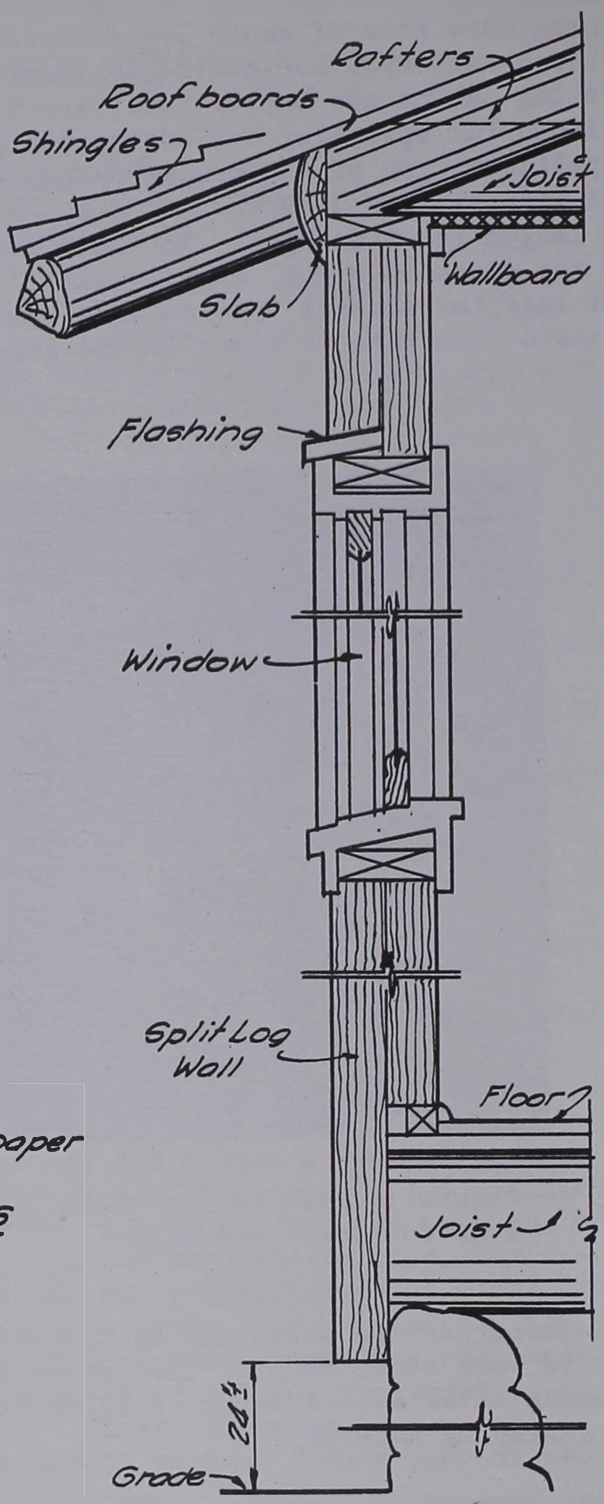
The interior of the cabin may be finished by using waterproof building paper or some other form of insulation which is covered by the inside finishing material. A layer of split aspen logs, or plywood, makes a good finishing material.

Another type of construction just coming into use is of the block type. Aspen blocks three to eight inches in diameter and six to eight inches in length are laid flat with the axis of the bole at right angles to the wall. The spaces in between the blocks are filled with cement mortar. It is believed, however, that the shrinking and swelling of the blocks may cause the mortar to crack.



TYPES OF SPLIT LOG WALLS

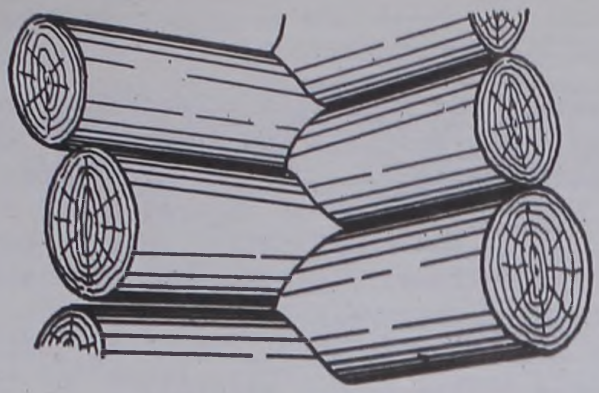
DETAIL AT DOOR AND PARTITION



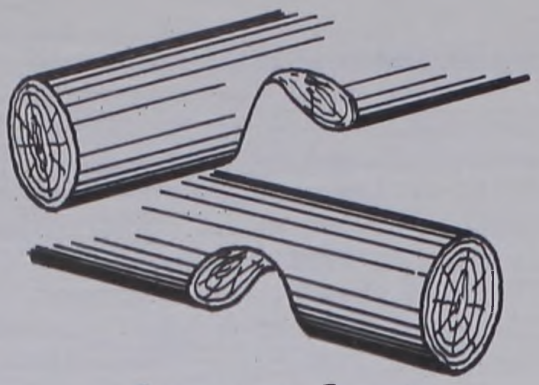
TYPICAL WALL CONSTRUCTION

SPLIT LOG CONSTRUCTION DETAILS

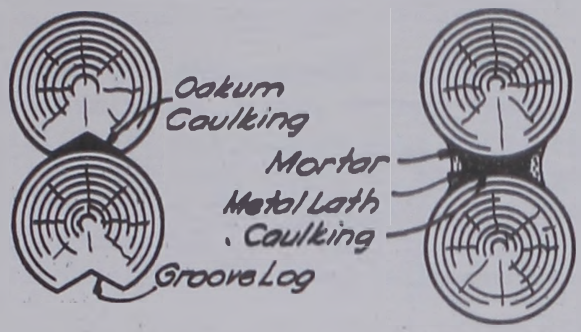
FIG. 2

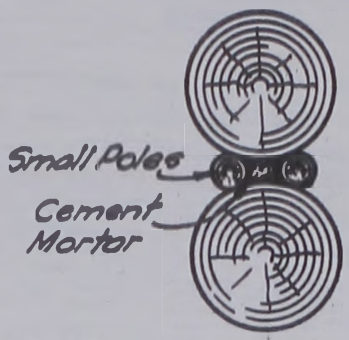


CORNER DETAIL

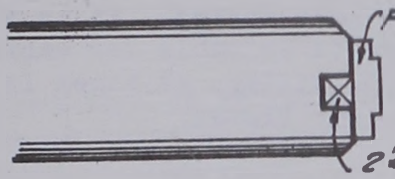


CUTTING DETAIL FOR CORNER





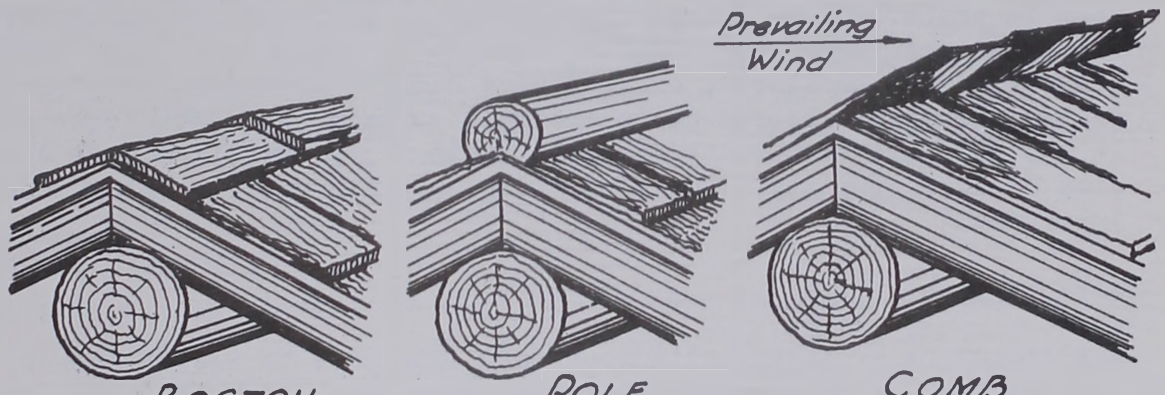
TYPES OF WALL CONSTRUCTION



Note. Allow space at top of frame for radial shrinkage of 2% per log from green dimension.

METHOD OF SETTING DOOR & WINDOW FRAMES

HORIZONTAL LOG CONSTRUCTION DETAILS



BOSTON POLE COMB

LOG CABIN RIDGE TREATMENT

FIG. 3

Construction Details

Much information on construction details is available in architectural and structural engineering publications. Actually the fundamental details of log construction are relatively simple. The few most important details of log cabin construction are illustrated in Figures 2 and 3. Further information on log cabin designs and construction details can be obtained from U. S. Department of Agriculture, Miscellaneous Publication 579, "Building with Logs", University of Wisconsin Circular 158, "Log Buildings", Michigan State College Extension Bulletin 222, "Log Cabin Construction", and other publications listed under "Literature" at the end of this report.

Supply of Aspen

Aspen occupies a larger area in the Lake States than any other forest type. Recent estimates by the Lake States Forest Experiment Station show about 20 million acres of aspen type within the three Lake States. Minnesota, with 7,500,000 acres, leads in aspen type acreage, with Michigan and Wisconsin dividing the remaining area about equally. This large acreage of aspen type contains an estimated merchantable volume of $6\frac{1}{2}$ billion board feet in trees over nine inches in diameter at breast height.

With this large acreage and volume of aspen, cabin log material is in abundant supply in each of the three Lake States. It is estimated that at least 25% of the board foot volume is suitable for cabin logs. This supply is within reach of every cabin builder, as aspen is well distributed throughout the northern half of the Lake States.

Specifications.

Cabin log material should be fairly uniform in diameter and the logs should have a minimum of taper. The choice of species is important. When durable species are available at a reasonable cost, they should be used in preference to a less durable wood. Red pine and cedar have an excellent reputation as cabin log material. Aspen logs, made durable by a preservative treatment, or when used without treatment away from the ground, have also proven to be entirely suitable for cabin construction. In the purchase or cutting of aspen cabin logs, specifications concerning size of logs, quality, time of cutting, peeling and seasoning, are very important.

Size of Logs

The diameters of aspen cabin logs vary from five to twelve inches, with logs in the six to nine inch diameter range most commonly used. Lengths vary from 8 to 36 feet. The shorter lengths for fill-in between wall openings can be salvaged from logs which do not meet specifications. The palisade type of construction utilizes 8-foot lengths with longer lengths being used in horizontal log construction. It is difficult to find aspen trees which are clear and straight without defects which will yield the

longer length cabin logs. Actually, lengths in excess of 20 feet are seldom necessary, as the length of the rooms is rarely more than 20 feet. Splicing of logs is possible but spliced logs weaken the building and detract from its appearance. Buildings should be designed so as to eliminate the need for logs in excess of 20 feet in length. Because of the difficulty of handling long logs and finding trees which will yield such logs, the trend has been toward palisade type construction.

Quality

Aspen logs should be reasonably straight, free from rot, surface scars, bird pecks and discoloration. Sweep should not exceed two inches per eight foot section. Rot is especially objectionable as it weakens the log and may serve as a means of access for insects and a place for moisture to collect thereby stimulating further decay. Uniform diameters of logs with a minimum taper are preferred.

Time to Cut

Fall and winter are the best times to cut aspen for cabin log material. Aspen cut in spring and early summer peels very easily, but during this time of the year conditions are favorable for attacks by insects and decay organisms. Fall and winter cut logs have time to dry sufficiently by summer so that they are less subject to insect and disease attacks. Logs cut in the spring and summer check quite badly due to rapid surface drying.

Peeling

Peeling of aspen logs is recommended for all kinds of structures as the wood deteriorates quite rapidly if the bark is not removed. Aspen logs should be peeled as soon after cutting as possible. This is especially important if the logs are cut in the spring or early summer because of almost certain damage from bark beetles if the bark is not removed. While fall and winter cut aspen does not peel as readily as spring or summer cut aspen, the extra cost of peeling is offset by the resistance to insect and disease attack. Peeling of fall and winter cut aspen requires the use of a draw knife or similar tool and streaks of the inner portion of the bark adhere to the logs. When the logs are to be treated with a preservative, bark streaks are objectionable. Bark prevents penetration of preservatives and in time falls off the log exposing untreated wood.

Seasoning

Aspen logs should be well seasoned before they are used. As soon as logs are cut and peeled, they should be piled on skids spaced about six feet apart. The skids should be at least 10 inches in diameter so that air circulation under the pile will be possible. Stickers should also be placed between each layer of logs to insure plenty of air circulation within the deck. The proper seasoning period will depend on weather conditions and will range between three and six months. The builder should

allow plenty of time for seasoning in order to reduce shrinking and checking to a minimum after the cabin has been built. Excessive shrinking and checking causes cracks and ill fitting joints, which detract from the serviceability and appearance of the cabin.

Durability of Aspen as a Cabin Log Material

Decay resistance of native species of wood lies in the heartwood. Sapwood of practically all species has low resistance to decay and consequently is not durable when exposed to conditions favoring decay organisms. The best measurement of durability of wood is, therefore, based on the ability of the heartwood to resist decay. The following table classifies the most common native species in eastern United States as to durability.

Table #1

Durable	Intermediate Durability	Low Durability	
Eastern red cedar	Red pine	Ash	Spruce
Northern white cedar	Tamarack	Beech	Balsam Fir
Chestnut	Red Oak	Birch	Aspen
Black locust	White pine	Hemlock	Basswood
Black walnut	Jack pine	Hickory	Cottonwood
White oak		Maple	Yellow poplar
			Elm

Aspen is classed as wood of low durability and should not be placed close to the ground without a preservative treatment to prevent decay. Foundations of stone or masonry should extend about two feet above the ground line and the ground should slope gradually away from the building for drainage. Storm water must not be allowed to accumulate around the foundation. Wide eaves and down spouts are important so that water is directed away from the building and not allowed to drop and splash the logs near the ground. In the construction of the building, extreme care should be taken to insure close fitting joints (Fig. 4) throughout so that moisture cannot accumulate in cracks and crevices and stimulate decay.

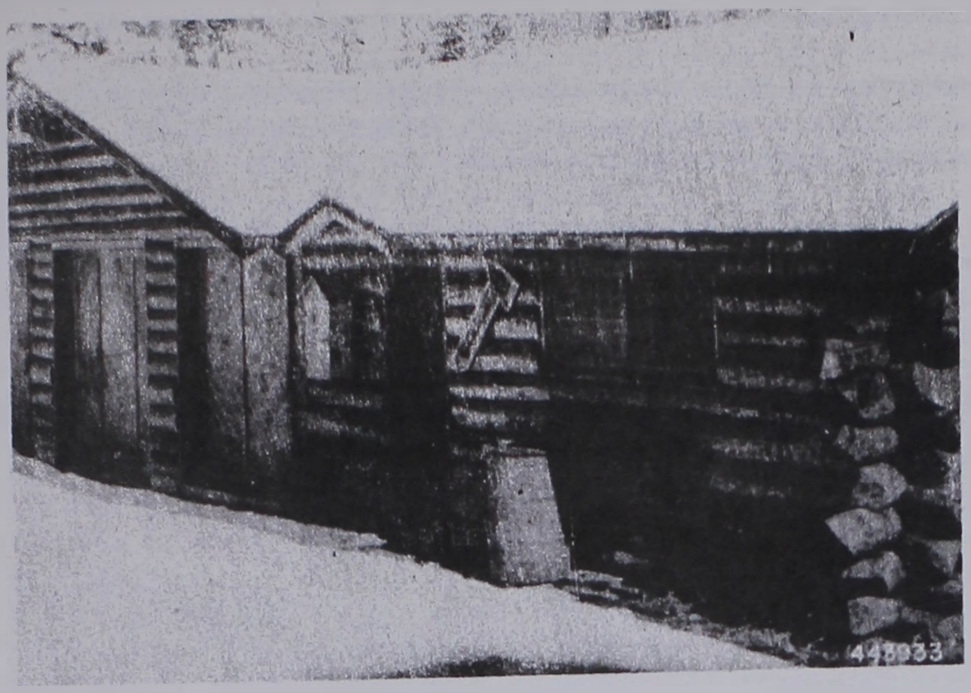


Figure 4. Halfway Ranger Station garage built with aspen logs showing tight fitting joints and corner construction. F-443933

Most log cabins if properly constructed and maintained will have a satisfactory life without preservative treatment. However, when aspen logs are used it is recommended that a preservative treatment be given those logs in close proximity to the ground. This preservative treatment should be applied to the logs before the structure is erected in order to secure maximum effectiveness.

There are many preservatives which are effective in preventing decay. Some are objectionable for specific uses because of their color and odor. Coal tar creosote is the most widely used wood preservative, but its use in preserving cabin logs is limited because of its color and odor. However, it can be used for preserving logs resting on and just above the foundation, foundation timbers and elsewhere in the structure where color and odor are not objectionable. Certain advantages such as toxicity to wood-destroying fungi and insects, ease of application, and its general availability and relatively low cost, should be weighed against the disadvantages of creosote for preserving cabin logs.

When a light colored and odorless preservative is desired, zinc chloride, chromated zinc chloride and some of the chlorinated phenols should be considered. The chlorinated phenols are being used more extensively each year and are excellent preservatives for cabin logs. Zinc chloride

and chromated zinc chloride are water-soluble wood preservatives and likewise are being used extensively in the United States.

Zinc chloride is relatively cheap, light colored, odorless, and wood treated with this preservative will take and hold paint well. Its chief disadvantage, however, is its solubility in water.

There are several non-pressure processes used in the application of preservatives. These processes are all less effective than pressure treatment and should be used only when it is impractical to use pressure treatment. The "hot-and-cold-bath" treatment is the most commonly used non-pressure process and is the most effective. The wood is placed in an open tank with the preservative and heated for several hours at a temperature of about 230 degrees Fahrenheit, then removed from the hot preservative and placed in a cold bath for several hours. Coal tar creosote is the preservative most commonly used in the hot-and-cold bath process, but zinc chloride may also be used if care is taken to keep the solution at uniform strength.

The steeping process is another non-pressure method used to a considerable extent in Europe. The process is simple and consists of placing the material in a tank of preservative solution allowing it to soak for about a week. A longer soaking time results in better absorptions. Mercuric chloride is most commonly used but zinc chloride, chromated zinc chloride, sodium flouride and other water soluble salts can be used. Mercuric chloride can be used only in concrete or wooden tanks because of its corrosiveness. Extreme care should be used in handling the preservative because of its high toxicity to humans.

The simplest and one quite commonly used in preserving cabin logs is the brush treatment. This is the least effective method, but if properly applied will materially reduce the possibility of decay. Creosote and similar oils are used and should be applied hot for best results. Care should be taken to see that the entire log is covered and all cracks should be filled with the preservative. At least two coats should be applied, the subsequent coat after the previous one has dried. Brush treatment using zinc chloride or other soluble salts is not recommended.

Most cabins are given an exterior and interior finish. Various mixtures of linseed oil and varnish have been used with good results. One mixture recommended is 25% varnish and 75% linseed oil for exterior finish. Raw linseed oil, coal tar creosote or any dark finishing stain are satisfactory for exterior finishing. Experience has shown, however, that frequent applications, at least one every two years, is needed for best results. The use of cabin log paint has become prevalent during the past few years. The paint is yellow-brown in color and after a year or so of weathering gives the impression of a natural log surface.

The average life of any log cabin depends to a considerable extent on location and workmanship of construction. A well constructed aspen log cabin located on a well aerated site will outlast a poorly constructed pine or tamarack cabin located on a low moist site.

The U. S. Forest Service has used aspen in the construction of a number of cabins with marked success. A ranger station was constructed on the Superior National Forest in 1916, using the palisade type of construction. It was torn down in 1934 and the logs were still well preserved. Other buildings have been constructed since and many are over 10 years old with no evidence of deterioration. The Halfway Ranger Station on the Superior National Forest constructed of aspen logs in 1934 (Fig. 5) and in good condition illustrates a type of building erected by the U. S. Forest Service.

Figure 5. Halfway Ranger Station office constructed of aspen logs showing entrance construction, windows, roof drain and corner construction. F-443936

It is believed that aspen structures will last as long as spruce, balsam fir, pine or hemlock, if care is taken in the construction and preservative treatment is given to the logs likely to be exposed to excessive moisture.

Comparative Cost of Aspen with Other Woods

Aspen is the cheapest cabin log material found in the Lake States. Not too many years ago aspen was considered a weed species because no market existed for its products. Large quantities of high grade material rotted on the stump. Today a market exists and large quantities are used for pulpwood and lumber, but the price for stumpage is still considerably less than the price received for pine, spruce, balsam fir, cedar or hard-

woods, such as maple, birch, cak and basswood. Aspen stumpage in the Lake States averages about $5.00 per M in contrast to $10.00 to $25.00 per M for coniferous species most commonly used in cabin construction. Pine and spruce are in most demand and because of quality and the limited supply command the highest prices.

Future Outlook

The use of aspen as a cabin log material has increased during the past 10 years. This use should continue to increase. The extent of the increase will depend on how well research agencies and educational institutions keep the consuming public informed on factors influencing the use of this wood. In the past, many people considered aspen to be unsatisfactory for cabin construction because poor construction methods had given the wood a poor reputation. Even today aspen is considered by many people as a weed species and suitable only for low grade pulpwood and lumber. This poor reputation is gradually being overcome by the increasing consumption of aspen for lumber and products made from lumber as well as by a better understanding of the wood's shortcomings and how to reduce or eliminate these shortcomings. Aspen, properly used, has proven to be a good cabin log material. This fact alone will have a marked effect on the future use of aspen for cabin construction.

Literature

T. A. N. Miller

The use of logs and poles in farm construction. U.S.D.A. Farmer's Bulletin 1660. Government Printing Office, Washington, D. C. 1931.

Forest Products Laboratory

Making cabin logs endure. (R982) Forest Products Laboratory, Madison, Wisconsin. Rev. 1946.

S. A. Wetzel

Log Buildings, Circular 158, Extension Service, University of Wisconsin, Madison, Wisconsin. 1935.

A. B. Bowman

Log Cabin Construction. Extension Bulletin 222, Michigan State College, East Lansing, Michigan. 1941.

C. P. Fickles and W. E. Groben

Building with logs. Misc. Publication 579, U. S. Dept. of Agriculture, Forest Service, Washington, D. C. 1945.

Conrad E. Meinecke

Your Cabin in The Woods. Published by Foster & Stewart, Buffalo 3, New York. 1945.

LAKE STATES ASPEN REPORT NO. 16

ASPEN FOR EXCELSIOR

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PROCESSED BY
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LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (Populus tremuloides) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up to date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

Report Number	Subject
1	Aspen Properties and Uses
2	Aspen Availability and Supply
3	Logging Methods and Peeling of Aspen
4	Milling of Aspen into Lumber
5	Seasoning of Aspen
6	Aspen Lumber Grades and Characteristics
7	Mechanical Properties of Aspen
8	Machining and Related Properties of Aspen
9	Aspen Lumber for Building Purposes
10	Aspen for Containers
11	Aspen for Core Stock
12	Small Dimension and Other Industrial Uses of Aspen
13	Aspen for Veneer
14	Aspen for Pulp and Paper
15	Aspen for Cabin Logs
16	Aspen for Excelsior
17	Aspen Defiberization and Refining of Product
18	Chemical Utilization of Aspen
19	Preservative Treatment of Aspen
20	Marketing of Aspen
21	Possibilities of Managing Aspen

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REPORT NO. 16

ASPEN FOR EXCELSIOR

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The use of aspen for the manufacture of excelsior is well established in the Lake States. The properties of the wood make it suitable for this general use, and there are adequate supplies available for increased productive capacity. The process of manufacturing excelsior is relatively uncomplicated, and the production equipment is simple and relatively low in cost. That the industry is not more extensive is obviously due to limitations in markets for excelsior. Expansion of the industry depends primarily upon the development of new uses and new products having excelsior as a base.

HISTORY OF THE INDUSTRY

Excelsior manufacture has been characterized by shifts in species and major markets and a reduction in volume produced since its original development in this country in 1860 (2).

Basswood was the original favored species. Later aspen and cottonwood became the leading excelsior woods. These species are closely related and both have properties similar to basswood and have long been more economically available. In areas where these species are scarce, pine has become an acceptable excelsior wood and is even preferred for some product uses.

Excelsior was originally used mainly for mattress stuffing. As more satisfactory materials were developed and designs were improved, this market for excelsior was reduced to only the less expensive mattresses. Upholstery was once a major use for excelsior, but the amounts absorbed by this market have declined as preference has shifted to more satisfactory materials. Packing for fragile merchandise has been the major use for excelsior for many years. In recent years, competing packing materials, which have proven either more specially suitable or cheaper, have displaced excelsior to a considerable extent. These shifts, in major uses, have caused excelsior manufacture to lag behind general business activity.

There has been a reduction both in number of plants manufacturing excelsior and in total volume produced, but the mortality of plants has been more severe than the decline in production. The larger plants, with lower costs and better marketing facilities, have tended to survive. In 1909 there were 109 excelsior plants in this country (4).

The number had been reduced to 75 in 1923 (4), and 53 in 1939 (5). In the post-war period 3 additional plants came into production.

Volume produced was nearly 190,000 tons in 1929 (3) and 123,000 tons in 1939 (5). In 1947 the production had recovered to approximately 152,000 tons (6). The recent increase has, of course, been due to improvement of general business activity. It is probable that a major portion of this increase has been in terms of a closer approach to capacity production in established plants rather than new productive capacity.

It is significant to note that while total production of excelsior increased about 24 percent, production of baled or bulk excelsior increased only about 13 percent from 1939 to 1947. Excelsior manufactured into pads and wrappers increased about 64 percent during the same period (6). Part of this increase has been due to shortages of competing materials. Except for these specialized forms of packing material, there has been very little excelsior remanufactured into products by excelsior manufacturers.

The conclusion to be drawn from the history of the industry is that the use of bulk excelsior has not kept pace with general economic development in this country. Survival of plants, in the face of shrinking markets, has apparently depended upon the ability to expand sales effort and to remanufacture the primary product for special uses.

MANUFACTURING PROCEDURE

Excelsior wood is usually purchased as peeled cordwood with a minimum diameter of about 4 inches and a maximum diameter, without splitting, of about 7 inches. The common cordwood length in the Lake States is 55 inches with squared ends.

The wood needs to be air-dried before use. This requires the manufacturer to maintain a raw material inventory equivalent to 12 to 18 months' production. Unpeeled wood begins to deteriorate before drying is completed. When it has been necessary to accept unpeeled aspen because of labor shortages in the forest, some manufacturers have resorted to mechanical peeling at the plant. Excelsior wood is usually procured from small producers through contracting agents.

The 55-inch sticks are reduced to 18-inch bolts before entering the excelsior plant.

Conventional excelsior machines are simple in principle and require little skill in operation. The cutting element is similar to that of a carpenter's hand plane with the addition of spurs to cut the "shaving" into ribbons. Adjustment of the feed and spacing of the spurs determine the size or "grade" of excelsior produced. The blade is suspended in a sliding frame that reciprocates along the axis of

the wood bolt. The bolt is gripped on each end by a fluted feed roll which advances the bolt into the blade at each pass of the frame. Although many machines in use are the single-place vertical type, the most modern model in common use has a horizontal action with places for 8 bolts. The single operator for this machine places the bolts in the feed rolls and removes the thin slab before it slivers.

From the excelsior machine, the product goes directly to the baling machine or to a remanufacturing department. In large plants the material is picked up automatically on a conveyor belt. Sometimes, before baling, the bunched excelsior is passed through shaking equipment to remove objectionable fine fibers. The baling equipment is the conventional type used for hay or straw. The bales usually weigh 100 or 200 pounds.

At plants where pads and wrappers are manufactured, the excelsior is conveyed to a department where it is stuffed into paper sleeves or bags by special machinery.

CHARACTERISTICS OF THE INDUSTRY IN THE LAKE STATES

Excelsior manufacture in the Lake States evidently accounts for somewhat more than half of the national production. In 1946 this segment of the industry received over 95,000 standard cords (9). At approximately one ton per cord this is equivalent to more than 60 percent of the total national shipments of excelsior products for 1947.

There were 7 plants active in the region in 1946, and one of these was destroyed by fire during that year. Four other plants, representing about 10 percent of the total productive capacity in the region, were reported as idle during that year (10).

It may be seen that the excelsior industry in this region is set up generally in large production units. They are large enough to maintain independent sales organizations and to develop markets. They can adapt themselves more easily to changing market conditions than can small-scale manufacturers. All of the large plants have been established for many years. One large excelsior organization in the area is engaged in the remanufacture of parts of its primary product into pads and wrappings, primarily for the furniture industry.

Several of the larger plants are located in areas which, because of local timber depletion, no longer have ready access to the more abundant sources of excelsior wood.

Two of the larger plants are located in industrial communities where wage rates are affected by higher skills than are required in excelsior manufacture.

Both aspen and basswood are acceptable for excelsior wood in the Lake States, but 94 percent of the supply used in 1946 was aspen (9). The

cost of the raw material has been affected by competition from pulp mills in the Lake States, which have been demanding aspen in increasing quantities in recent years. It has been the leading single pulpwood species cut in the Lake States for the past several years. In 1947 it amounted to more than 25 percent of pulwppd produced in the region (11). Both pulp mills and excelsior plants generally are located at a considerable rail haul distance from the major supplies of aspen.

PROPERTIES OF ASPEN

One of the principal properties that make aspen specially suited for excelsior is its fine uniform texture. This contributes to the uniformity and strength of the excelsior ribbons. Aspen is much superior in this respect to the ring-porous hardwoods and the coarse-grained softwoods which are likely to yield excelsior strands that vary in density and strength even in a single strand. Aspen excelsior may be handled or used without developing excessive broken strands. Its general straight grain contributes to the uniformity of the individual strand.

Aspen is low in density and yet tough and resilient in the form of ribbons. It fills in space firmly around fragile items without contributing greatly to the weight of the package. The massed strands of excelsior are able to maintain a spring tension against a packed article or to recover from deformation as a padding material. Aspen excelsior pads and wrappings may be twisted and bent into various shapes to conform to the parts of products that need protection in crating.

Aspen is very light in color and this is a considerable advantage in its use in excelsior for packing consumer goods. It may be colored readily for use in display packaging. Because of its lack of odor, it may be used in connection with the packing of foods that are easily tainted.

From the standpoint of excelsior manufacture, aspen is ideal because it occurs in large quantities in sizes adaptable for use in conventional machines without splitting.

USES FOR EXCELSIOR

The uses of excelsior are quite varied (8), although most of them account for only a small fraction of the total consumption, and these minor uses are constantly changing according to economic conditions and technical developments with competing materials.

There are two aspects of excelsior use. In one, it fills the requirements for a material that will fill space at the cheapest possible cost. This is the category represented by the major portion of excelsior consumption, and it is vulnerable to competition from many types of packing materials that can be produced and delivered to some consuming points at a slightly lower cost. In this use category, the

main advantage aspen has over other woods is cheapness. These uses may be satisfied more economically by other species in regions where they are available.

In another aspect of excelsior use it fills a requirement for a material designed for a specific technical function. In this category of use excelsior must compete with natural or synthetic materials which may be more costly but technically more suitable for a number of specific individual uses. In many cases competing materials may be engineered to exact use specifications. Excelsior is virtually limited to variation of species and strand size in its adaptation to specific technical uses.

Excelsior is marketed by grades which define the dimensions of the ribbon (13). There are three standard grades all having the same thickness of 1/100 inch. Fine is 1/26 inch wide, medium 1/8 inch wide, and coarse is 7/32 inch wide. Special grades may be produced in almost any size. Extra fine grades are called wood wool in this country and may be as thin as 1/500 inch and as narrow as 1/64 inch. Extra coarse grades may be 1/50 inch or more in thickness and 1/4 inch or more in width. The finer grades are more costly because excelsior machine blade speeds are constant and manufacturing rates are controlled by ribbon thickness.

The most common use for excelsior is in packing fragile items such as glassware, china, and other general merchandise by hand. It is extremely well suited for this use, being cleaner and more durable than many competing materials. Its best adaptability is in the packing of special orders by hand. Common substitute materials are straw and shredded newspaper. Superior materials have been developed for some special packing problems such as absorbent materials, for packing liquid-filled glass containers. The development of mass production manufacturing and packaging techniques has probably contributed to the decline in the use of excelsior packing. Other materials, such as corrugated board, have been more adaptable to package design for modern large scale manufacturing.

Excelsior-filled paper pads and wrappers represent a technical advancement in the industry which is evidently still developing. While bulk excelsior volume declined from 151,000 tons to 111,000 tons between 1929 and 1947, pad and wrapper manufacture increased from 32,500 tons to 41,000 tons in the same period (6). These products are used principally in the protection of furniture and other finished articles that are shipped in crates or unenclosed. Commonly, excelsior pads and wrappers are suitable for re-use in the shipment of household goods. Some pads filled with shredded paper are on the market, but unlike the excelsior product the paper sleeve needs to be heavy enough to bear all of the tearing stresses. This use for excelsior is one that is susceptible to further development through packaging engineering.

Mattress stuffing was originally a major use for excelsior, but only the most inexpensive mattresses now have any excelsior component in this country. Some crib mattresses have an inner core of fine excelsior. Other materials commonly used in low-cost mattresses are technically inferior to excelsior but appear to have greater customer acceptance.

Excelsior is still used to some extent in upholstery. It is used only as an inner component covered with padding materials of softer texture in some inexpensive lines of furniture. Excelsior evidently is deficient in durability under constant use as an upholstery padding material. Further, except for the extra fine grades, excelsior gives off a characteristic and objectionable harsh sound when compressed in use.

Excelsior seems to be most suitable in the manufacture of commodities in which permanence and durability in use is not a prime requirement. Manufacturers of toys use considerable quantities in stuffing dolls and toy animals. Some finer grades are used to a limited extent in both gas and liquid filtering, and the extra fine grades are suitable as absorbent material. In Europe, where other fibrous materials are comparatively scarce, the manufacture and use of the finer grades of excelsior is highly developed. There, refined "wood wool" is a commonly accepted substitute for absorbent cotton and gauze surgical pads.

A use for coarse excelsior, that appears to have possibilities for further development, is the manufacture of structural insulating board. Essentially, the bunched strands are bonded with an inorganic cement and formed into panels or slabs (7). The excelsior is usually impregnated with a chemical by dipping, in order to increase its fire resistance and aid the adhension of the binding material. Most often the binder is Portland cement or magnesite which is mixed with excelsior in the form of a thin slurry. After the excess slurry is drained off, the mass is placed in forms for the initial setting time under low pressure. After removal from the forming equipment, the product is usually stored in air for a curing period. The usual product is a panel from one to three inches in thickness. The mineral component coats the wood ribbons and binds them together in a porous mass as it sets.

Because of the time required for the setting of Portland cement, it is believed that board forming with this binder has so far not been successfully done as a continuous process; the panels are formed in individual molds. One European manufacturer, using magnesium oxysulphate as a binder, employs a continuous forming and heat-curing machine (1, 14).

The excelsior-type panel is unique as a building material because of its versatility. Its low density gives it excellent heat and sound insulation properties, and at the same time it is strong enough to

assume part of the load in structural design. Its rough surface provides an excellent base for stucco, plaster, or cement wearing surface and also provides excellent acoustical properties and decorative texture when used without additional surfacing. The material may be nailed and sawed with ordinary woodworking tools. Since the wood ribbons may be impregnated with fireproofing chemicals and are thoroughly coated with inorganic cement, the product has high fire resistance.

Panels of this material are suitable for use alone in interior non-bearing partitions. The thicker panels may be used as single-unit exterior walls when suitable column supports are incorporated in construction. In this case the exterior surface needs to be sealed from the weather by stucco or other suitable weatherproof material. The interior surface may be plastered directly on the panel or covered with other interior-finishing material. In the form of thick slabs this material is suitable for roof decking. Here, a topping of Portland cement is applied to the slab and conventional roofing material is applied as a weathering and waterproofing surface. The thicker slabs are suitable for floor planks to be laid directly on properly spaced joists. The wearing surface in this case is a fairly thick layer of Portland cement. The one-inch board may be used as conventional insulating board as exterior sheathing or interior panels. An interesting application is its incorporation on the inside of concrete walls by using the excelsior boards as the inner form boards.

Excelsior-based boards are in fairly common use in many European countries and there are four products of this type known to be manufactured in this country, mostly on a limited scale.

POSSIBILITIES OF EXTENDING THE USE OF ASPEN FOR EXCELSIOR

Apparently the traditional markets for excelsior have been shrinking for some time. Thus, these markets do not offer much hope for expansion in excelsior manufacturing facilities under normal operating conditions. The greatest inroads into the excelsior markets have been made by those materials which have become available at lower cost, and the only possibility of meeting this competition entails reduction of the market price of excelsior.

There are considerable possibilities for reducing raw material costs through mechanization of excelsior timber harvesting. This operation represents the dominant element in wood costs, and it is almost entirely involved with hand labor.

It is conceivable that production costs for excelsior manufacture could be generally reduced. Mechanization could be improved by adopting the most modern machines available or by the development of new excelsior machines involving less labor cost. Such new machines would

probably be adaptable only to large-scale production and development would depend upon large additional market outlets.

Some general cost reduction could be gained by locating excelsior plants as close as possible to aspen timber supplies. This would allow direct shipment of raw material from forest to plant by truck and avoid the expense of car loading and long rail hauls. Placing the plants in the forest area would also make available unskilled labor at lower cost than in urban locations.

The best possibilities of expanding excelsior production lie in the development of new markets based on new uses. Industry is becoming increasingly conscious of the necessity for package engineering. Apparently the field is wide for the adaptation of excelsior to special packing problems as opposed to its use in bulk for hand packing.

The building industry is in the mood to adopt materials that have been proven to be technically superior and more economical than conventional home-building materials. The success of the excelsior-type boards in Europe and their versatility indicate that this product has good possibilities for market development in this country.

Technical information on excelsior is extremely rare. Virtually no engineering data are available on the properties of excelsior and little is known about methods to improve these properties. It is probable that a general research program on this material would form the basis for expanded use in many phases of industry. Without a technical background, excelsior must continue to yield markets to the engineered materials of modern industry.

LITERATURE CITED

(1) Aisher, O. A., Bessey, G. E., Blenkensopp, W. K., Freedlander, M. J., and Morris, E.
1947. The German Wood Wool Building Slab Industry. British Intelligence Objectives Sub-Committee, Item 22h, 63 pp. (typed). (Library of Congress, Photoduplication Service, PB 75867.)

(2) Brown, N. C.
1927. Forest Products: Their Manufacture and Use. John Wiley, New York. 447 pp.

(3) Bureau of the Census.
1933. Census of Manufacturers: 1929. U. S. Department of Commerce.

(4) _____
1935. Biennial Census of Manufacturers: 1931. U. S. Department of Commerce.

(5) _____
1942. Census of Manufacturers: 1939. U. S. Department of Commerce.

(6) _____
1949. Census of Manufacturers: 1947. Preliminary Industry Report, Excelsior Mills. Series MC76C-1. 2 pp. (mimeo).

(7) Close, Paul D.
1946. Building Insulation. American Technical Society, Chicago. 372 pp.

(8) Forest Products Laboratory.
1941. Excelsior and its Manufacture. Forest Products Laboratory Unnumbered Report. 3 pp. (mimeo).

(9) Horn, A. G.
1948. Lake States Operators Increase Cut of Excelsior Wood -- 1946. Lake States Forest Experiment Station, Tech. Note 294. 1 pp. (mimeo).

(10) _____
1948. Unpublished data. Lake States Forest Experiment Station.

(11) _____
1948. Lake States Pulpwood Production Decline in 1947. Lake States Forest Experiment Station, Tech. Note 301. 2 pp. (mimeo).

(12) Kollman, F.
1936. Technologie des Holzes. Julius Springer, Berlin. 764 pp.

(13) Morbeck, Geo. C.
1948. Excelsior Manufacture. Forest Products Laboratory. Report No. R 1711. 3 pp. (mimeo).

(14) Thorogood, A. L.
1948. Supplementary report on the German Wood Wool Building Slab Industry. British Intelligence Objectives Subcommittee. 71 pp. (typed). (Library of Congress, Photoduplication Service, PB L 87925.)

LAKE STATES ASPEN REPORT NO. 17

ASPEN DEFIBERIZATION AND REFINING OF PRODUCT

BY

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SCHOOL OF FORESTRY AND CONSERVATION

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FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

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REPORT NO. 17

ASPEN "DEFIBERIZATION" AND REFINING OF PRODUCT

By

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Because of the great demand for wood fiber and because there is an abundance of aspen available[1/] for this purpose, its conversion into a usable fiberized material offers possibilities. It also affords an outlet for low-quality bolts developed in any aspen logging operation or from land of poor quality.

Allis-Chalmers Defiberizer

The "defiberization" of wood waste or of little-used wood species offers one means of obtaining high yields of fibrous material at a relatively low cost. At present the chief users of fiberized aspen are the roofing manufacturers. The felt made in a few mills for this purpose contains an appreciable quantity of this fiber and it has been found to absorb the asphalt in a satisfactory manner.

The shredded type of fiber produced by this method from round wood or slabs without prior chipping makes the method unique when compared to other methods of producing coarse fiber pulps. Since no process water is required, an important advantage of the Defiberizer is that it can be installed in a small plant at the source of wood or woods waste and the product can be baled immediately and shipped to a converting mill. If cheap power is available, a low-cost fiber can be produced by this method at a rate of about 1 ton per hour per machine.

The Defiberizer converts low-grade wood into a form which offers possibilities for the development of a number of products such as a filler for sandwich board construction, the manufacture of Fibercrete (a combination of fiber with Portland cement), fiber plaster, and various kinds of fiberboard. Of a total production in 1946 of about 1,600,000 tons of high-grade, coarse-fiber pulp, it is estimated that only 50,000 to 60,000 tons (about 3 percent) were produced by Defiberizers.

The Defiberizer converts wood into fiber by mechanical means. Perhaps a more strict definition of the material produced would be shredded wood, rather than fiber. The individual shreds consist mostly of bundles of fibers and therefore do not have the same qualities as the refined fiber used in making paper. Were the defiberized wood more flexible, it might be used to a greater extent by the roofing manufacturers.

1/ See Lake States Aspen Report No. 2, "Aspen Availability and Supply," by Clarence D. Chase, Lake States Forest Experiment Station (St. Paul, Minnesota), June 1947.

The Defiberizer consists of a rigid steel frame into which are fitted two cylinders approximately 30 inches in length and 16 inches in diameter. To these cylinders numerous small sharp-pointed hammers are attached by rods extending along the axis of the cylinder. These hammers swing freely on the rods. The combination of the cylinders and the small hammers is called a brush. The sharp-pointed hammers are the bristles of the brush.

Above the brushes a hopper is mounted having an over-all length of 66 inches, divided into two compartments of 33 inches each. The hopper is 30 inches wide at the bottom with sides tapering to a top opening of 26 inches. The height of the hopper is 36 inches on the loading side and 48 inches high at the back. This hopper travels on four wheels 7 inches in diameter at a speed of 10 to 32 cycles per minute over the revolving brushes.

The bolts of wood to be made into fiber are not rossed; they are used in lengths of from 24 to 30 inches and are placed in the hopper in such a position that the fiber is removed from the tangential surface of the bolt. The action of the revolving brushes on the moving bolt produces the fiber. The resulting fiber can be sold as such or can be refined in an attrition mill to any degree of fineness desired.

The fact that this process provides a profitable means of utilizing wood of relatively low quality is of great importance. Many fire-scarred, insect or fungus-damaged pieces are usable. Poor-quality wood that naturally develops in any aspen operation and wood that has grown on sites of poor quality are usable. However, experience has shown that when knots are abundant the cost of machine maintenance is increased.

The aspen fiber made by this process heretofore has been mostly from round wood. However, the manufacture of fiber from slabs and edgings by this process offers possibilities. One mill on the West Coast now is using slabs. The hopper of the machine would have to be redesigned to take care of slabs and edgings instead of bolts. Narrower and shorter compartments might be necessary to keep the slabs and edgings in the proper position but the slabs and edgings could be fed into the hopper in exactly the same manner as the bolts, and the final product should be the same.

The yield from a standard cord of slabs and edgings would not be as high as from a cord of logs, and the expense of handling would be greater. However, slabs and edgings are waste material and must be disposed of in some way, and this costs money. If they can be converted into fiber from which even a small profit can be realized, it is better than to dispose of them as domestic fuel and to bother with many small accounts.

Coarse Grinding

In this process, pulpwood is ground in an ordinary pulpwood grinder fitted with a coarse-grit stone dressed with a much rougher grinding surface than is employed in the production of paper pulp.

Processes Involving Chipping and Fiberizing

In the processes described above, the wood to be reduced to fiber was used in bolt form. A number of processes are possible where the wood is reduced to chips, using an ordinary paper mill chipper for the purpose. The chips are given a simple treatment before being reduced to fiber. The treatment given the chips may be one of the following:

a. Soaking in water.

b. Steaming.

c. Semichemical cooking to varying degrees of intensity using a variety of chemicals.

Some of the methods by which the wood is used in the form of chips are as follows:

The Asplund Defibrator.--Unlike the fiberizing process previously described, the material fed into the Asplund Defibrator is first reduced to chips in a standard pulpmill chipper. The chips, with or without pulping chemicals, under steam pressure at a temperature of 175° to 200° C., are forced by a plunger or a screw feed mechanism against revolving refining disks which reduce the solid pieces of wood to a fibrous mass.

The Pandia Fibrilator.--This machine treats wood with steam by a continuous process similar to the Asplund Defibrator. It is sold without the attrition mill and may therefore be used in conjunction with any milling machine. In this case, however, the milling is not conducted under elevated steam pressures and temperatures.

The Masonite Process.--This consists of heating chips with high-pressure steam and then blowing them from the retort. The chips are "exploded" by the sudden release of pressure and are fiberized further by impact against a target.

Milling of Treated Chips.--After the chips have been treated by one of the above methods, one of the following mills can be used to reduce them to fiber:

a. Interplane Grinder
b. Bauer Mill
c. Jordan Engine
d. Rod Mill
e. Beater

If the fiber is to be used at once in the manufacture of some product, nothing further need be done. If the fiber is to be shipped, it must be converted to a damp or dry condition and baled.

Fiber Quality

In defiberized material it is necessary to keep in mind that we are dealing with a material of low strength but still strong enough to be made into such products as wallboards and felts. Since we are considering fiber with low strength values and a rather narrow field of utilization, the raw material must be abundant and cheap and the fiber must be produced at low cost.

When producing low-cost and low-strength fiber, two desirable qualities are penetrability and flexibility. If these qualities can be obtained, more of this kind of fiber could be used in certain products and additional uses might be developed.

Previously it was stated that fiber might be sold directly from the defiberizer and could be refined in an attrition mill. This refining process reduces the size of the individual shreds and to that extent makes them more flexible than the coarser shreds; however, it does nothing to the fiber itself to improve its flexibility.

At present it appears that converting wood into chips, then giving it some sort of treatment, and finally reducing it to fiber in an attrition mill will become an acceptable method of producing this kind of low-cost fiber.

It should be thoroughly understood that the manufacture of this class of fiber is at present in a state of flux. No one knows the best way to handle the various kinds of woody material that naturally find their way into this type of product. Considerable more research is needed in the next few years. When improved methods have been worked out, an important advance in better utilization of mill waste and low-grade aspen will have been made.

LAKE STATES ASPEN REPORT NO. 18

CHEMICAL UTILIZATION OF ASPEN

BY
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PROCESSED BY
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (*Populus tremuloides*) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up to date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

Report Number	Subject
1	Aspen Properties and Uses
2	Aspen Availability and Supply
3	Logging Methods and Peeling of Aspen
4	Milling of Aspen into Lumber
5	Seasoning of Aspen
6	Aspen Lumber Grades and Characteristics
7	Mechanical Properties of Aspen
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REPORT NO. 18

CHEMICAL UTILIZATION OF ASPEN

PART I: WOOD

By

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Introduction

Chemical utilization of raw materials depends largely on the chemical composition and the chemical and physical properties of the raw materials under consideration. The utilization of wood is no exception to this principle. Thus, a wood having a low percentage of cellulose is uneconomical as a source of wood sugar or pulp for paper; and one of an excessively knotty character is undesirable for chemical conversion. Woods having several undesirable characteristics generally fall within the classification of species little used for the purpose. Fortunately, aspen falls outside this class.

Chemical Composition of Aspen Wood

The chemical composition of sound aspen is similar in most respects to that of several hardwoods, among which are yellow birch and sugar maple. Analytical data on the chemical composition of the three woods are recorded in table 1 and will be considered briefly as a means of comparing aspen with the other two woods, also indigenous to the Lake States. So far as the analytical values are concerned, quaking aspen compares favorably with yellow birch and sugar maple.

Extractives

Extractives are designated as materials soluble in neutral solvents, such as water, alcohol, alcohol-benzene mixtures, and ether. They form no part of the wood structure. A cursory examination of the analytical values recorded in table 1 suggests that, so far as extractives are concerned, nothing extraordinary on a quantitative basis is derivable from aspen or the other two woods. Extractives from aspen have received no serious commercial consideration. They are divided into four classes, cold-water, hot-water, alcohol-benzene, and ether extractives.

1/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Wisconsin, Madison, Wisconsin.

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Table 1.--Analysis of woods (percentages based on weight of oven-dry wood)

Wood	Ash	Extractives soluble in				Acetyl	Meth-oxyl	Pento-sans	Lignin	Holo-cell-ulose	Cross and Bevan cellu-lose	Alpha cellu-lose
		Cold water	Hot water	Alcohol benzene	Ether							
	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent
Quaking aspen	0.30	1.00	2.00	1.52	1.00	5.10	5.31	22.50	17.3	79.50	63.50	51.0
Yellow birch	.40	1.00	1.28	1.40	.31	7.42	5.90	26.86	19.3	77.00	58.75	49.7
Sugar maple	.42	.68	1.12	1.24	.45	5.52	6.40	22.81	22.3	75.20	60.40	50.0

Cold-water extractives constitute 1.50 percent of aspen as compared with 1.00 and 0.68 percent from yellow birch and sugar maple, respectively. In general, these extractives comprise sugars, gums, salts, and also tannins if present in the wood. Hot-water extractives in aspen make up 2.00 percent of the wood as compared with 1.28 and 1.12 percent in birch and maple, respectively. These extractives comprise sugars, gums, tannins, and starches. Alcohol-benzene extractives from aspen are equivalent to 1.52 percent as compared with 1.40 and 1.24 percent from birch and maple. They comprise oils, fats, fatty acids, waxes, sterols, and also some tannins, if present, from hardwoods, with the additions of resins and terpenes from softwoods. Ether extractives comprise 1.00 percent of aspen as compared with 0.31 and 0.40 percent from birch and maple, respectively. They are composed of oils, fats, fatty acids, waxes, and sterols from hardwood, with the addition of resins and terpenes from softwoods.

Minor Chemical Groups

Acetyl constitutes 5.1 percent of aspen as compared with 7.4 and 5.5 percent, respectively, in birch and maple. It is also designated as a substituent chemical group of the wood hemicelluloses with which it is combined as an ester. Acetyl, on hydrolysis, as in sulfite semi-chemical production of pulp, is converted to acetic acid. The acid is used in numerous commercial operations, such as the manufacture of rayon, plastics, solvents, adhesives, artifical leather, and curing and flavoring of foods. Methoxyl constitutes 5.3 percent of aspen as compared with 5.9 and 6.4 percent in birch and maple, respectively. It is associated with both the lignin and the hemicelluloses in the form of an ether. When removed by hydrolysis, methoxyl forms methanol (wood alcohol). In the destructive distillation of wood, one-fourth to one-third of the methoxyl is converted to methanol, the remainder being destroyed during the operation. Methanol is employed as a solvent and in the manufacture of plastics, rayons, airplane dopes, ethers, adhesives, and other materials.

Wood Constituents

Pentosans constitute 22.5 percent of aspen, 26.8 percent of birch, and 22.8 percent of maple. On hydrolysis, pentosans are converted to pentose or 5-carbon sugars known as xylose or arabinose, depending on the constitutional configuration of the pentosans. On treatment with mineral acids under specified conditions, pentosans are converted to furfural, which is employed extensively in the refining of wood rosin and petroleum oils and in the manufacture of plastics and rayons. The pentose sugars are unfermentable to ethanol by the conventional types of yeasts; only the hexose sugars are fermented to alcohol.

Lignin constitutes 17.3 percent of aspen. This value is low compared with 19.3 and 22.3 percent respectively from yellow birch and sugar maple. Lignin is the principal material that holds the fibers of the wood together, only a small percentage of hemicellulose material functioning similarly. Since aspen has a low percentage of lignin, it

is an excellent raw material for chemical wood pulps from the standpoint of low chemical requirement for the pulping operation.

The chemical requirement for pulping of wood varies with the percentage of lignin in the wood. On the weight basis, the chemical requirements for pulping aspen would be approximately 17/19 and 17/22 of that required for yellow birch and sugar maple, respectively.

Lignin in general is considered a waste product in the manufacture of chemical fibers for paper. In the sulfite pulping process it passes into the streams as a wood waste. Since aspen contains a low percentage of lignin, it is less an offender in this respect than birch or maple.

Cellulose Materials

Values for three cellulose materials are listed in the last three columns of table 1. It seems desirable, before discussing the values, to explain briefly the preparation and the nature of the cellulose materials. Holocellulose is a solid wood residue prepared by removing the lignin by chlorinating the wood, and then dissolving the chlorinated lignin so formed with an ethanolamine-alcohol solution. The residue is a white, lignin-free fibrous cellulose product comprising practically all the cellulosic material in the wood. Alpha cellulose is the portion of holocellulose or any lignin-free cellulose material insoluble in 17.5 percent aqueous sodium hydroxide solution under specified conditions. Cross and Bevan cellulose is a white lignin-free cellulose fraction of wood obtained by chlorinating the wood and dissolving the chlorinated lignin with dilute aqueous sodium sulfite solution. In general, it comprises from 55 to 62 percent of the wood, depending on the species.

It may be noted in table 1 that aspen has 79.5 percent of holocellulose, 63.5 percent of Cross and Bevan cellulose, and 51.0 percent of alpha cellulose. These values are higher than the corresponding values from birch or maple. The results for the holocellulose and the Cross and Bevan cellulose show that aspen surpasses the other two species in holocellulose and Cross and Bevan cellulose on a weight basis. They suggest it should be a good source for refined chemical pulps for papers, and also for rayon and other cellulose derivatives, as indicated by the high alpha cellulose yield.

Aspen is a light wood, weighing 22 to 24 pounds per cubic foot on an oven-dry green-volume basis. Thus a cord of 85 cubic feet weighs less than an equal volume of some other wood. The weight of holocellulose, Cross and Bevan cellulose, and alpha cellulose in a cord of aspen, yellow birch, and sugar maple is recorded in table 2.

Table 2.--Percentage of cellulose in cord of wood on oven-dry green-volume basis

Species	Weight per cord	Cellulose per cord		
		Holocellulose	Cross and Bevan	Alpha
	Pounds	Pounds	Pounds	Pounds
Quaking aspen	1,870	1,486	1,187	953
Yellow birch	2,890	2,225	1,697	1,436
Sugar maple	2,970	2,233	1,793	1,485

Sapwood and Heartwood

Bigtooth aspen is also an important wood. It is similar to quaking aspen in structure, composition, and chemical and physical properties. Some valuable qualitative data on both the sapwood and the heartwood of this species are recorded in table 3 (4) 2/. It may be noted that what has been said about the low lignin, the high Cross and Bevan cellulose, and the high holocellulose values of quaking aspen also applies to bigtooth aspen. The lignin content is 16.3 and 16.9 percent for the sapwood and the heartwood, respectively. The holocellulose yields are 78.0 percent for the sapwood and 80.0 percent for the heartwood. As may be noted in table 3, aspen compares favorably in composition with beech, yellow birch, paper birch, and sugar maple.

Further, aspen contains 80.0 percent of holocellulose, of which, on the wood basis, 22.5 percent is pentosans. This leaves 57.5 percent of the wood substance in aspen as hexosans. These hexosans, on hydrolysis, are converted to hexose sugars. Accordingly, aspen, even though it is a hardwood, should be a good source of wood sugar for fermentation to ethyl alcohol, conversion to molasses, or for propagation of fodder yeast.

Summative Components

In a rather complete analysis, as recorded in table 3, some overlapping of the values occurs. The cold-water extractives are also included in the hot-water extractives; methoxyl values are included in the lignin and the holocellulose values; and the pentosans and the acetyl values are included in the holocellulose. Wood can be divided into four component parts - extractives, ashes, lignin, and holocellulose. Thus a summative analysis of wood comprises determinations of the above four summative components (5) as recorded in table 4, in which are listed bigtooth aspen with beech, yellow birch, paper birch, and sugar maple.

2/ Underlined numbers in parentheses refer to Literature Cited at end of Part I of this report.

It may be noted that aspen is similar to the other four woods in that values of the four summative components are equivalent to approximately 100 percent of the oven-dry wood.

Composition of Cellulosic Fractions

A chemical analysis of aspen cellulose fractions showed that good quantitative data on the composition of the materials are obtainable (2). Thus, an analytical breakdown of the holocellulose and the Cross and Bevan cellulose according to the data in table 5 accounts for practically 100 percent of the two materials.

An analysis of wood sometimes comprises the determination of four cellulose fractions of the material (wood). They are (1) holocellulose, (2) Cross and Bevan cellulose, (3) hydrolyzed holocellulose, which is the residue remaining after holocellulose is hydrolyzed with 1.3 percent sulfuric acid for 2 hours, and (4) alpha cellulose. Differences in the degradation of these cellulose fractions can be determined by dispersing separately samples of each in a suitable solvent and measuring their viscosity. For example, samples from the least degraded dispersed cellulose fractions will flow most slowly from a viscometer tube.

In table 6 are recorded the yield and the viscosity (3) of holocellulose, Cross and Bevan cellulose, hydrolyzed holocellulose, and the alpha cellulose from each of the three fractions. As a means of comparison, the cellulose materials were prepared by the same procedure from quaking aspen, white spruce, red spruce, jack pine, balsam fir, and eastern hemlock, all commonly used as sources for pulps intended for papers.

It may be noted in table 6 that the values for the yield and the viscosity of the six cellulose fractions from the quaking aspen compare favorably with the yield and viscosity values for the corresponding cellulose fractions from the other five species. Aspen has 82.5 percent of holocellulose as compared with values ranging from 73.3 to 68.5 percent for the other five species. Aspen has 64.1 percent of Cross and Bevan cellulose as compared with yields ranging from 61.2 to 56.0 percent for the remaining woods. Aspen also leads the other five species in hydrolyzed holocellulose content with 63.7 percent as against values ranging from 61.0 to 55.3 percent from the other woods. It leads the other five woods in alpha cellulose yields from the holocellulose, the Cross and Bevan cellulose, and the hydrolyzed holocellulose, as may be noted in table 6.

Viscosity values are recorded in centipoises in table 6. Aspen holocellulose has a viscosity of 40.2 centipoises. Jack pine holocellulose has a viscosity of 50.1 centipoises. The holocellulose viscosities from the other four species range from 35.4 to 20.1 centipoises. Aspen Cross and Bevan cellulose has a viscosity of 28.9 centipoises, which is higher than the viscosity of the corresponding cellulose fraction from the other five woods.

Table 3.--Composition of American woods1/

Chemical composition	Bigtooth aspen		Beech		Sugar maple		Paper birch		Yellow birch	
	Sap-wood	Heart-wood	Sap-wood	Heart-wood	Sap-wood	Heart-wood	Sap-wood	Heart-wood	Sap-wood	Heart-wood
Ash	0.26	0.33	0.31	0.57	0.32	0.84	0.24	0.21	0.11	0.50
Solubility in:										
Cold water. . . .	2.70	1.36	2.33	.23	.81	.52	1.28	1.12	1.20	.93
Hot water	3.13	.99	2.17	.43	2.08	1.20	2.39	2.15	1.30	1.29
Alcohol-benzene .	2.41	2.13	1.37	.96	1.31	1.22	3.31	6.44	.97	1.89
Ether	1.02	1.03	.20	.57	.10	.89	.79	2.19	.36	.30
Acetyl.	5.48	6.07	7.13	6.05	6.56	4.94	7.12	7.60	8.79	6.11
Methoxyl.	5.27	5.35	6.28	6.44	6.34	6.50	6.10	5.75	6.01	6.04
Pentosan.	23.33	23.75	25.55	24.49	22.78	22.98	28.77	28.64	26.89	26.87
Lignin2/.	16.33	16.92	20.61	22.26	20.33	21.79	17.56	19.61	18.56	20.19
Cellulose	62.67	64.42	60.83	60.71	60.39	60.27	55.58	50.96	59.36	58.37
Cellulosan.	14.45	15.78	17.88	18.33	16.02	14.25	17.98	13.97	19.27	16.99
Holocellulose . . .	78.01	80.00	76.20	76.85	76.26	75.96	76.61	70.85	79.50	76.45
In holocellulose3/										
Acetyl.	5.17	5.05	5.15	4.76	5.12	4.05	6.01	5.29	6.13	5.81
Methoxyl.	.65	.72	.95	1.24	.83	.97	.97	.95	1.31	.93
Pentosan.	22.51	22.98	24.46	23.52	22.67	22.57	28.45	26.93	26.49	24.94

1/ Results in percentages of oven-dry (105° C.) wood.
2/ Ash-free.
3/ Percentage on original wood.

Table 4.--Composition of American woods, 1/ summative analysis

Species	Ash	Solubility in		Lignin	Holocellulose	Total
		Hot water	Alcohol-benzene			
	Percent	Percent	Percent	Percent	Percent	Percent
Bigtooth aspen						
Sapwood. . .	0.26	3.13	2.41	16.33	78.01	100.14
Heartwood. .	.33	.99	2.13	16.92	80.00	100.37
Beech						
Sapwood. . .	.31	2.17	1.37	20.61	76.20	100.66
Heartwood. .	.57	.43	.96	22.26	76.85	101.07
Yellow birch						
Sapwood. . .	.11	1.30	.97	18.56	79.50	100.44
Heartwood. .	.50	1.29	1.89	20.19	76.45	100.32
Paper birch						
Sapwood. . .	.24	2.39	3.31	17.56	76.61	100.11
Heartwood. .	.21	2.15	6.44	19.61	70.85	99.26
Sugar maple						
Sapwood. . .	.32	2.08	1.31	20.33	76.26	100.30
Heartwood. .	.84	1.20	1.22	21.79	75.96	101.01

1/ Results in percentages of oven-dry (105° C.) wood.

Table 5.--Composition1/of quaking aspen holocellulose and Cross and Bevan cellulose

Fractions and chemical groups	Holocellulose	Cross and Bevan cellulose
	Percent	Percent
Alpha cellulose..	61.4	76.3
Pentosans.....	26.7	19.9
Uronic acids.....	5.0	2.6
Acetyl.....	5.5	1.6
Methoxyl.....	1.1	.7
Totals.....	99.7	101.1

1/ Percentage values based on weight of oven-dry materials

Table 6.--Yield and viscosity of cellulosic materials from various woods1/

Species	Holocellulose	Cross and Bevan cellulose	Hydrolyzed holo-cellulose	Alpha from -		
				Holo-cellulose	Cross & Bevan cellulose	Hydrolyzed holocellulose
Quaking aspen:						
Yield.....	82.5	64.1	63.7	50.7	48.3	47.3
Viscosity.....	40.2	28.9	11.2	72.3	39.6	18.0
White spruce:						
Yield.....	73.3	61.2	61.0	49.5	44.6	43.7
Viscosity.....	32.7	17.2	13.7	68.2	23.8	21.1
Red spruce:						
Yield.....	72.9	60.3	60.5	48.3	43.4	43.3
Viscosity.....	35.4	18.8	11.6	56.7	30.1	18.4
Jack pine:						
Yield.....	72.5	58.3	59.1	49.5	43.2	43.1
Viscosity.....	50.1	26.9	15.8	77.7	29.2	21.1
Balsam fir:						
Yield.....	69.9	56.4	55.3	44.0	39.8	39.3
Viscosity.....	20.1	19.7	6.4	39.2	24.0	19.3
Eastern hemlock:						
Yield.....	68.5	56.0	55.4	48.2	43.2	41.7
Viscosity.....	23.0	20.3	8.5	36.1	23.5	20.9

1/ Percentage yield based on weight of oven-dry wood; viscosities expressed in centipoises in cuprammonium solution.

The viscosity of the alpha cellulose from aspen holocellulose is 72.3 centipoises. The corresponding value from jack pine is 77.7 centipoises; and the corresponding values from the two spruces, balsam fir, and eastern hemlock range from 68.2 to 36.1 centipoises. Aspen alpha from Cross and Bevan cellulose has a viscosity of 39.6 centipoises; it excels the viscosity of the corresponding cellulose fractions from the other five species.

These viscosity data indicate that aspen compares favorably in its resistance to the degradative effects of the chemical treatments involved in the preparation of the wood-cellulose fractions listed in table 6; aspen also should be a good source for cellulose fibers with good strength properties desirable for fabrication into yarns and films of various cellulose derivatives.

Aspen Holocellulose and Hemicellulose

Thomas (1) made a valuable contribution to the chemistry of aspen in his research on aspen holocellulose and hemicellulose. The latter is the material that dissolves when lignin-free cellulose is treated with a 17.5 percent aqueous sodium hydroxide solution. He prepared aspen holocellulose by chlorinating wood sawdust that was first slightly moistened with water and then suspended in carbon tetrachloride. The chlorinated sawdust was extracted with alcohol-monoethanolamine solution for the removal of the chlorinated lignin. The procedure avoided heating of the sawdust during chlorination, which occurs if the material is not suspended in a liquid for dissipating the heat generated during chlorination. It also reduced the possibility of degrading the holocellulose.

The yield of holocellulose on an ash-free basis was 77.5 percent. This high yield is another confirmation that aspen is a good potential source for cellulose, as stated earlier in this report. Thomas also carried on a rather extensive extraction operation for removing, stepwise, hemicelluloses from the holocellulose. The holocellulose was (a) given three 12-hour extraction treatments with cold water; (b) the residue was given three 4-hour extraction treatments with hot water; (c) the residue from the hot-water treatment was given two 2-hour extraction treatments with 5.0 percent potassium hydroxide; and (d) the residue from the 5.0 percent alkaline extraction was given two 1-hour treatments with 15.0 percent potassium hydroxide solution.

The filtrate from each of the above extractions was treated separately with alcohol to precipitate the hemicelluloses. Refining of the hemicelluloses was carried out by alternately dissolving and reprecipitating them with alcohol.

Yields

By the series of water and alkaline extractions about 27.0 percent of hemicelluloses was obtained from the aspen holocellulose, recorded in table 7 (values for fractions A to E, inclusive, in column (2)).

Calculated on the basis of the weight of the wood, the yield of the hemicellulose extracted was equivalent to about 20.8 percent (values for fractions A to E, inclusive, in column (3)).

Acetyl

The hemicelluloses A, B, and C in column (4) are shown to have between 8 and 9 percent acetyl groups which are undisturbed by the water extractions. On the other hand, acetyl is removed from the hemicelluloses by alkaline extractions, which accounts for the fact that no acetyl is shown in fractions D and E and in the cellulose residue. These results confirm the evidence that acetyl groups are associated largely with the hemicelluloses from aspen.

Methoxyl

Methoxyls, which on hydrolysis form methanol (wood alcohol), were associated with the various hemicellulose fractions to the extent of 2.34 to 2.48 percent, which confirms the modern concept that not all the methoxyl in wood is associated with the lignin.

Uronic Acids

Uronic acids comprised from 11.0 to 23.4 percent of the hemicellulose fractions.

Xylan and Glucosans

Except for fraction C, xylan comprises from 54.2 to 85.5 percent of the aspen hemicellulose fractions. No araban, also a pentose-forming material, was detected by Thomas. Glucosans in yields of 5.0 to 8.6 percent were present in the aspen hemicelluloses.

In general, the results of Thomas are in agreement with those of others who have worked on aspen. The low lignin and high cellulose content of the wood suggest the species to be a good hardwood source for cellulose in good yields, at moderate cost of chemicals required for delignification operations.

Aspen Cellulose Fibers

Cellulose fibers from aspen average approximately 1 mm. in length and their diameter is about 1/50 mm. Delignified fibers from holocellulose comprise about 35.4 percent of hemicelluloses (27.5/77.5 = 35.4), and 64.6 percent of alpha cellulose (100 - 35.4 = 64.6). On the basis of the wood, the hemicellulose content is about 27.5 percent and that of alpha cellulose 50.0 percent. These values are the approximate potential yields of hemicelluloses and alpha cellulose. The value for hemicelluloses, however, is higher than that recovered from aspen holocellulose. So far the value of 20.8 percent (on the basis of the wood) obtained by Thomas appears to be the upper limit of hemicelluloses recovered from aspen holocellulose.

Table 7.--Yield and composition of aspen holocellulose and hemicellulose fractions

Fractions (1)	Yield1/ on basis of holocellulose (2)	Yield2/ on basis of wood (3)	Acetyl3/ (4)	Methoxyl3/ (5)	Uronic3/ anhydride (6)	Xylan3/ (7)	Glucosans3/ (8)
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Holocellulose	100.00	77.50	3.37	0.88	5.40	20.10	65.20
Hemicellulose A C.W.a/	3.26	2.52	8.91	2.34	17.10	57.30	5.00
Hemicellulose B H.W.b/	4.20	3.26	8.12	2.48	23.40	54.20	5.50
Hemicellulose C H.W.Ac/	2.58	1.99	8.94	2.40	12.10	8.00	7.50
Hemicellulose D	11.30	8.75	0.00	1.70	14.60	82.70	8.60
Hemicellulose E	5.54	2.30	.00	1.70	11.00	85.50	7.90
Cellulose residue	65.30	50.60	.00	.15	.50	1.58	....

1/ Yield of fractions on ash-free, lignin-free basis, calculated on weight of oven-dry holocellulose.
2/ Yields calculated on weight of extractive-free, oven-dry wood.
3/ Composition of fractions on ash-free, lignin-free basis calculated for oven-dry materials.

a/ Soluble in cold water.
b/ Soluble in hot water.
c/ Soluble in hot water and also alcohol; recovered by evaporation of alcohol.

Suggested Possible Chemical Uses for Aspen Wood

The composition of the delignified aspen fibers suggests that with further research they should be useful for the following purposes: (1) On account of their high hemicellulose content, they should be convertible to glassine-like and greaseproof papers with low power consumption. (2) Their high alpha cellulose content suggests that they would be a good source for materials intended for the manufacture of cellulose derivatives. (3) They should also be suitable for making high-yield bleached cellulose fibers for making white papers. (4) Their high hexosan material suggests that it should be possible to hydrolyze aspen carbohydrates to high yields of hexose sugars, most of which can be converted to ethanol by yeast fermentation. (5) The high holocellulose content suggests that aspen should be a good source of sugars for conversion to molasses or propagation of fodder yeast.

Literature Cited

(1) Thomas, B. B.
1945. Isolation and Analysis of Hemicellulose Fractions from Aspen Holocellulose. Paper Industry and Paper World 27(3): 374-378, 382.

(2) Van Beckum, W. G., and Ritter, Geo. J.
1939. Composition of Holocellulose, Hydrolyzed Holocellulose and Cross and Bevan Cellulose. Paper Trade Jour. 108(7): 27.

(3) Van Beckum, W. G., and Ritter, Geo. J.
1939. Yield and Viscosity of Holocellulose and Some of Its Cellulosic Fractions. Paper Trade Jour. 109(22): 107.

(4) Wise, L. E.
1944. Wood Chemistry. Amer. Chem. Soc. Monograph, p. 666.

(5) Wise, L. E.
1944. Wood Chemistry. Amer. Chem. Soc. Monograph, p. 667.

CHEMICAL UTILIZATION OF ASPEN[1]

PART II: BARK

By

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Introduction

The chemical utilization of a forest crop in the production of the higher-grade papers and purified cellulose or high alpha pulp involves, in general, the problem of removal and disposal of the bark. This is particularly important in the case of aspen since the relatively small diameter of the tree reduces the ratio of wood to bark to the extent that as much as 15 to 20 percent of the harvested material may be bark. One of the controlling factors in the chemical utilization of aspen is the economic balance between cost of raw material and the recovery of salable product in the form of cellulose fiber. Under present methods of utilization in the higher-grade products, the cellulose fiber must bear the cost of removal and disposal of bark. This situation has been responsible for the economic idleness of large areas of smaller diameter second-growth aspen on the poorer sites, of which there are more than 3 million acres in Minnesota alone.

It is the purpose of this report to outline the present knowledge of the nature and chemical composition of aspen bark to aid in making it an asset rather than a liability. The information which is presented includes a discussion of the general characteristics of the bark and its chemical composition.

Characteristics of Aspen Bark

Aspen bark is notably variable in appearance from smooth and light colored to rough and dark. The normal bark is smooth and grey in color, with a powdery efflorescence consisting of sloughing periderm cells, and typically waxy in feel. The rough and darker colored bark is associated with abnormal periderm formation, apparently resulting from mechanical injury or attack by fungi and lichins (3).

The proportion of bark and its thickness as found on stems of various diameter classes from 1 to 11 inches is given in table 1 (4).

1/ Published as University of Minnesota Department of Agriculture Misc. Journal, Series No. 597.

Table 1.--Weight and thickness of aspen bark as related to tree diameter

Stem diameter	Average thickness	Average weight in percent of total weight of wood plus bark	
		Green	Oven-dry
Inches	Inches	Percent	Percent
1	.09	30.2	29.5
2	.12	22.6	23.2
3	.14	19.7	22.2
4	.19	19.2	21.9
5	.21	17.1	20.1
6	.23	15.4	17.9
7	.24	14.4	17.2
8	.29	14.7	17.0
9	.30	13.8	16.4
10	.37	13.5	15.8
11	.47	13.3	15.7

Morphologically (4), aspen bark is composed of four well-defined layers which may be observed in microscopic sections or may be easily separated by mechanical means. The outer layer or periderm normally consists of from six to eight rows of more or less rectangular cells (0.029 x 0.020 mm.) and makes up about 2 percent by weight of the dry bark. The second layer or cortex appears as a soft green mass of slightly tangentially elongated parenchyma cells (0.069 x 0.026 mm.) and makes up about 17 percent of the dry weight of the bark. The third and fourth layers compose the secondary phloem and together amount to about 81 percent of the bark. The third layer is composed of fibers (average length, 0.94 mm.) intermixed with stone cells (average length, 0.035 mm.), as well as ray cells and other parenchyma, and amounts to about 67 percent of the bark, while the fourth layer consists almost entirely of fibers (average length, 0.98 mm.), ray cells, and other parenchyma, and composes about 13 percent of the bark. The stone cells seem to be concentrated in relatively large numbers in the third layer or outer portion of the secondary phloem. Although sieve tubes are, of course, present in the secondary phloem, they do not survive the maceration or pulping technique employed in studying the cellular composition of the bark.

Chemical Composition of Aspen Bark

The methods and results of studies of the chemical composition of a large variety of barks have been summarized in reviews by Segall and Purves (6), and by Kurth (5). Although the literature through 1946 is well represented in these publications, no reference is made to the chemical composition of aspen bark. However, unpublished results of research carried on by Wangerin (7) at the University of Minnesota give a partial indication of the general chemical composition of the bark. A proximate analysis of aspen bark is given in table 2.

Table 2.--A proximate analysis of aspen bark

	Bark
Ash	4.05
Cold-water solubility	20.53
Hot-water solubility	23.06
Ether solubility	15.13*
Alcohol-benzene solubility	23.52
Lignin	23.86
Holocellulose	60.63
Cellulose	38.72
Pentosan	18.54

*Davenport (Michigan Conservation, p. 4-6, Dec. 1937) reports an ether solubility of 13.95 percent in an analysis of deer browse. Other analyses at the University of Minnesota indicate a value of 8-9 percent. The differences may well be due to seasonal variation.

Aspen bark is noteworthy in its high content of extractable material (4), as indicated in table 3, where it may be seen that about 36 percent of the bark is removed by extraction with organic solvents and water, and a further 8 to 10 percent is soluble in dilute ammonium hydroxide, as determined by the method of Anderson (1) for the extraction of pectic materials from wood. The latter is at present thought to be composed of pectins or other uronic acid containing carbohydrates. The organo-solvent extractives are composed of fatty materials and glucosides, while the water-soluble extractives appear to be composed of mono- and disaccharides, as well as other water-soluble higher polysaccharides.

Table 3 shows the extent of extractives obtained from various bark layers when each is extracted successively with the solvent series, including petroleum ether, ethyl ether, benzene, alcohol, and hot water.

Table 3.--Extraction of aspen bark1/

Layer	Petroleum ether	Ether	Benzene	Alcohol	Hot water	Total2/ organic extract	Total3/ neutral extract	Pentosan in residue
Periderm	0.26	0.06	0.02	0.11	0.15	0.45	0.60	0.52
Second layer	2.56	.52	.22	5.45	4.55	8.75	13.30	2.35
Third layer	.71	1.14	.18	9.24	6.36	11.27	17.63	12.95
Inner layer	.35	.35	.07	2.25	1.83	3.02	4.85	1.98
Total	3.88	2.07	0.49	17.05	12.89	23.49	36.38	17.80

1/ Percent oven-dry weight of original whole bark.
2/ Successive extraction with petroleum ether, ether, benzene, and alcohol.
3/ Includes hot-water extract and total organic extract.

Calculations from these data show that 1.65 percent of the total extractive is found in the periderm, 36.5 percent in the second layer, 48.5 percent in the third layer, and 13.3 percent in the inner layer.

An analysis of the alcohol-benzene extract of aspen bark (2) indicates that about 90 percent of the extract is composed of phenolic glycosides along with a lipid fraction. The lipid fraction was found to consist of about 50 percent free fatty acid having an average chain length of 14 carbon atoms. The unsaponifiable portion amounted to about 25 percent of this fraction and was said to consist mainly of phytosterols, the latter being apparently responsible for the waxy appearance of the extract. The results are given in table 4.

Table 4.--Analysis of the alcohol-benzene extract of aspen bark

	Percent
Volatile substance (100° C, in vacuo).....	10
Lipid substances.....	15
Phenolic glycoside	
Water-soluble.....	40
Water-insoluble.....	35
Nitrogen (Kjeldahl).....	0.06
Phosphorous.....	0.05
Pentoses.....	Trace
Fusion temperature.....	75° to 85° C.

Pulping Characteristics

Although the pulping properties of aspen bark have not been extensively investigated, it has been found (4) that the bark may be disintegrated by cooking with reagents such as sodium hydroxide or sodium sulfite. However, the pulp residue leaves much to be desired. In the case of alkaline cooking reagents, the pulp is exceedingly granular and appears to be composed of small balls of fiber associated with conglomerates of stone cells. The cellular components of the periderm and cortex as well as parenchyma and rays are lost in the screening, the residue consisting almost entirely of secondary phloem fiber and stone cells. In the case of a sodium sulfite cook, the bark largely retains its original form but on mechanical disintegration and screening, the secondary phloem is retained in a shredded and unpulped state. Microscopic examination shows the shredded material to be thin tangential sections of the secondary phloem composed of parenchyma and fibers, the ray cells and most of the stone cells having been removed. Yields and analyses of the pulps obtained by various cooking reagents are shown in table 5.

Table 5.--Pulping of aspen bark1/

Reagent	Yield 2/	Cellulose 3/	Alpha Cellulose
	Percent	Percent	Percent
4 NaOH	26	79.1	73.5
8 Na_2SO_3	43	71.1	....

1/ Cook 2 hours at 160° C.
2/ Retained on Fourdrinier screen.
3/ Cross and Bevan.

Utilization

In the light of present knowledge of aspen bark, suggestions as to its possible utilization are, at most, extremely visionary. The yields and quality of fiber are not such as would encourage its use in any but low-grade fiber products. At present it is being used in the manufacture of wallboard where the nature of the product does not justify removal of the bark prior to pulping.

The mechanical separation of the inner fibrous layer of the bark from the outer nonfibrous materials appears to have possibilities and needs further investigation. Such separation might result in the production of a fiber from aspen bark that has possibilities in papermaking. A similar refining process is carried on with flax straw, in decorticating it for cigarette paper production.

If practical methods of recovery can be developed, the bark extractives appear to offer a possible source of chemical raw materials. However, the feasibility of such a method of utilization must await further information on the nature and composition of these extractives.

Literature Cited

(1) Anderson, E., et al.
1937. Pectic Substances from Wood, II. J. Biol. Chem. 121: 165.

(2) Briggs, D. R.
1944. Unpublished research on chemical composition of aspen bark carried out under a grant in aid from the Graduate School of the University of Minnesota.

(3) Kaufert, F. H.
1937. Factors Influencing the Formation of Periderm in Aspen. Am. J. Botany 24(1): 24-30.

(4) Kaufert, F. H.
1947. Unpublished research on chemical composition of aspen bark carried out under a grant in aid from the Graduate School of the University of Minnesota.

(5) Kurth, E. F.
1947. The Chemical Composition of Barks. Chem. Rev. 40: 33.

(6) Segall, G. H., and Purves, D. B.
1946. Chemical Composition of Wood Barks. Pulp and Paper Mag. of Canada 47(3): 149-162.

(7) Wangerin, R. R.
1941. A Chemical Analysis of Aspen Bark. M. S. Thesis, University of Minnesota.

LAKE STATES ASPEN REPORT NO. 19

THE PRESERVATIVE TREATMENT OF ASPEN

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FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (Populus tremuloides) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up to date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

Report Number	Subject
1	Aspen Properties and Uses
2	Aspen Availability and Supply
3	Logging Methods and Peeling of Aspen
4	Milling of Aspen into Lumber
5	Seasoning of Aspen
6	Aspen Lumber Grades and Characteristics
7	Mechanical Properties of Aspen
8	Machining and Related Properties of Aspen
9	Aspen Lumber for Building Purposes
10	Aspen for Containers
11	Aspen for Core Stock
12	Small Dimension and Other Industrial Uses of Aspen
13	Aspen for Veneer
14	Aspen for Pulp and Paper
15	Aspen for Cabin Logs
16	Aspen for Excelsior
17	Aspen Defiberization and Refining of Product
18	Chemical Utilization of Aspen
19	Preservative Treatment of Aspen
20	Marketing of Aspen
21	Possibilities of Managing Aspen

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REPORT NO. 19

THE PRESERVATIVE TREATMENT OF ASPEN[1/]

By

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Aspen is one of our least durable woods and is known to deteriorate or rot rapidly under conditions favoring decay. Records on aspen used under moist and severe decay conditions have shown that serious decay and failure of the product may develop in three to four years. Some present and potential uses for aspen involving conditions favorable to decay and in which this lack of natural durability is a factor are: (1) fence posts, (2) railroad cross ties, (3) mine timbers, (4) planking for secondary bridges, (5) sills and other construction members in buildings, (6) the lower logs of log cabins, and (7) small items as pickets, stakes, etc.

In all of these uses the wood in service is either in contact with the soil or is exposed to moisture for considerable periods, conditions that result in rapid deterioration or development of decay in woods lacking natural durability and not protected by an effective preservative treatment. Actually, aspen does not differ greatly from such hardwoods as black ash, green ash, basswood, hard maple, soft maple, paper birch, yellow birch, and cottonwood in durability or behavior under conditions favoring decay. None of these woods possess heartwood that differs appreciably from sapwood in decay resistance, and all of them are classed as species of low durability. Although there is considerable prejudice against aspen for uses in which decay is not a factor when good construction practices are followed, for such uses as siding, roof boards, sheathing, rafters, etc., experience has shown that aspen is as durable as any wood, either hardwood or softwood, under use conditions where it remains dry or is exposed to moisture for relatively short periods.

The preservative treatment of aspen is important only for products used under conditions favoring decay, such as the products listed in the first paragraph, which are used in contact with the soil or which may become moist and remain moist for considerable periods. Unfortunately, there is relatively little published information on the treating characteristics of aspen treated by different processes and with different preservatives. Consequently, most of the information on treating characteristics on which this report is based was obtained from discussions with operators of wood preserving plants in Minnesota and Wisconsin, who have had experience with aspen, and from the unpublished results of treating

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1/ Published as University of Minnesota Agricultural Experiment Station Misc. Journal Series No. 623

tests made at the Forest Products Laboratory and the University of Minnesota. The service records included in this report were summarized from a number of volumes of the Proceedings of the American Wood Preservers' Association. This report includes discussions on the wood rotting fungi responsible for most of the decay of aspen products, decay losses that occur during seasoning, the preparation of wood for treatment and treating characteristics, experience with various treating processes, the available service records on products treated with different preservatives by several processes, recommendations, and problems in need of added research.

THE FUNGI RESPONSIBLE FOR THE DECAY OF ASPEN

As is true for practically all tree species, rather distinct groups of wood-rotting fungi are responsible for the heartrot found in living aspen trees and the decay that develops in aspen pulpwood in storage, in ties during seasoning, and in all aspen products used in contact with the soil or under other moist conditions.

Fomes igniarius is responsible for most of the heartrot found in living aspen. Aspen is relatively short-lived, and trees on poor sites may have considerable heartrot caused by this fungus by the time they are 40 to 50 years of age (2). The same workers (Schmitz and Jackson) also showed that on better sites decay by Fomes igniarius may not become a serious limiting factor until stands reached 60 to 70 years in age.

In contrast to the heartrot of living aspen which is caused mainly by Fomes igniarius, a large number of wood-rotting fungi are capable of attacking and causing decay of aspen products. Some of the most common and important wood-rotting fungi found on decaying aspen products are several species of Polyporus (hirsutus, pargamenus, versicolor, adustus), several species of Poria, Fomes applanatus, Pleurotus ostreatus, and Armillaria mellea. Many other fungi may be found fruiting on decaying aspen products and may cause as rapid decay as the more common wood rots listed above.

LOSSES DUE TO DECAY

Because of the susceptibility of the wood to decay and the high moisture content of both sapwood and heartwood, aspen products may be severely attacked and heavy losses due to decay may occur during seasoning or storage unless special precautions are taken.

Unpeeled aspen pulpwood stored in the woods or in wood yards at mills may have numerous fruiting bodies or sporophores of wood-rotting fungi on it after storage for one summer. During particularly wet summers or under very adverse seasoning conditions, as when pulpwood is stored in brushy areas in the woods, decay may progress sufficiently in one season to cause considerable loss. Normally, however, unpeeled aspen pulpwood can be stored through one summer season without danger of serious loss, even though there may be considerable fruiting of fungi. During the second season, decay in unpeeled aspen pulpwood progresses very rapidly

decay losses are usually high, particularly when the wood is stacked
hat there is no space between stacks for air circulation or where the
yard is located in a place with poor air drainage. Peeled aspen
wood usually decays more slowly unless the wood is allowed to remain
he ground too long after peeling and becomes heavily infected before
king. Normally, peeled aspen pulpwood that has been correctly
led and is stacked under favorable conditions can be held through two
er seasons with no greater loss than occurs in unpeeled aspen during
season of storage.

problem of reducing decay losses in aspen pulpwood during storage has
given relatively little study. It is recognized that the best prac-
s is to limit storage to no more than one season, and this procedure
mally is followed. Getting the wood off the ground as soon as possi-
after cutting is important because it reduces the chances of infec-
n by decay fungi before the wood reaches the wood yard at pulp and
er mills. Stacking so that there is good air circulation between
es and placing not more than two 8-foot stacks together without an
space between them in yards where there is good air drainage are also
nerally recognized as being beneficial. The effect of spraying
ngicies or preservatives on the exposed ends of pulpwood sticks in
orage stacks was studied by the Division of Forestry of the University
Minnesota in 1940-41. Two fungicides 2/ extensively used in the dipping
lumber to prevent blue stain and decay during seasoning were used and
re applied to the exposed ends of pulpwood sticks in storage piles by
ans of knap-sack sprayers. The fungicies were applied in May 1940 on
peeled pulpwood cut and stacked in the yard during the previous winter.
jacent sections of the same stack were left untreated and acted as
ntrols. Examinations in August 1941, after two summers of storage,
owed a marked difference in the number of fruiting bodies of wood-
tting fungi on the ends of treated sticks as compared to untreated
icks. Also, there was much less decay near the ends of treated sticks
han in untreated material. However, within the stack, from 6 inches to
foot from the ends, there was no discernible difference between treated
nd untreated material. No pulping studies were made on this material,
o it was not possible to say whether such treatment would be economical
r worthwhile in case of wood for which storage through two summers is
nticipated. End treatment of pulpwood stacks has been found beneficial
y some southern paper mills, and it deserves further investigation for
spen pulpwood.

Serious decay losses may occur in aspen ties during seasoning. Much of
the prejudice against aspen ties stems from the difficulty that treating
plant operators have experienced during seasoning. The high moisture
content of aspen combined with its susceptibility to decay by a large
number of wood-rotting fungi makes it difficult to handle in the same
manner as ties from other tree species without danger of serious decay
losses. When regular stacking practices (one-by-nine) are followed,

2/ Lignasan (containing ethyl mercury phosphate as the active ingredient)
and Dowicide G or sodium pentachlorophenate.

d decay losses are usually high, particularly when the wood is stacked that there is no space between stacks for air circulation or where the od yard is located in a place with poor air drainage. Peeled aspen lpwood usually decays more slowly unless the wood is allowed to remain the ground too long after peeling and becomes heavily infected before cacking. Normally, peeled aspen pulpwood that has been correctly andled and is stacked under favorable conditions can be held through two mmer seasons with no greater loss than occurs in unpeeled aspen during ne season of storage.

he problem of reducing decay losses in aspen pulpwood during storage has en given relatively little study. It is recognized that the best prac- ice is to limit storage to no more than one season, and this procedure ormally is followed. Getting the wood off the ground as soon as possi- le after cutting is important because it reduces the chances of infec- ion by decay fungi before the wood reaches the wood yard at pulp and aper mills. Stacking so that there is good air circulation between piles and placing not more than two 8-foot stacks together without an air space between them in yards where there is good air drainage are also generally recognized as being beneficial. The effect of spraying fungicies or preservatives on the exposed ends of pulpwood sticks in storage stacks was studied by the Division of Forestry of the University of Minnesota in 1940-41. Two fungicides 2/ extensively used in the dipping of lumber to prevent blue stain and decay during seasoning were used and were applied to the exposed ends of pulpwood sticks in storage piles by means of knap-sack sprayers. The fungicies were applied in May 1940 on unpeeled pulpwood cut and stacked in the yard during the previous winter. Adjacent sections of the same stack were left untreated and acted as controls. Examinations in August 1941, after two summers of storage, showed a marked difference in the number of fruiting bodies of wood- rotting fungi on the ends of treated sticks as compared to untreated sticks. Also, there was much less decay near the ends of treated sticks than in untreated material. However, within the stack, from 6 inches to 1 foot from the ends, there was no discernible difference between treated and untreated material. No pulping studies were made on this material, so it was not possible to say whether such treatment would be economical or worthwhile in case of wood for which storage through two summers is anticipated. End treatment of pulpwood stacks has been found beneficial by some southern paper mills, and it deserves further investigation for aspen pulpwood.

Serious decay losses may occur in aspen ties during seasoning. Much of the prejudice against aspen ties stems from the difficulty that treating plant operators have experienced during seasoning. The high moisture content of aspen combined with its susceptibility to decay by a large number of wood-rotting fungi makes it difficult to handle in the same manner as ties from other tree species without danger of serious decay losses. When regular stacking practices (one-by-nine) are followed,

2/ Lignasan (containing ethyl mercury phosphate as the active ingredient) and Dowicide G or sodium pentachlorophenate.

drying is slow, and during poor-seasoning weather decay develops rapidly and abundant fruiting of fungi occurs at the points of contact between ties. Although decay may not develop sufficiently during one summer to affect strength or the later serviceability of well-treated ties, the material presents a bad appearance, and the contrast between aspen ties and ties of other species may be so great under poor seasoning conditions that the prejudice that has developed against aspen is quite understandable.

One treating plant operator reported that decay during seasoning can be greatly reduced by more open piling of ties, by stacking one-by-seven rather than the standard one-by-nine. This practice of providing about 2-inches of space between ties permits more rapid drying. Since aspen ties are not subject to serious checking during seasoning, such open stacking can be followed for this species, whereas it would result in serious checking of red oak, hard maple, and birch. It is difficult to introduce variations in stacking practices, and the cost of such open stacking is greater than the standard one-by-nine practice, but it offers a possible solution to the problem of reducing decay losses during seasoning of aspen ties. Replacing the cross tie used in self-sticking with a dry 2-by-4 has been suggested as another means of reducing decay losses during seasoning. Whether this practice is practical is not known.

Decay and stain damage to aspen lumber seasoning can be eliminated or held to a minimum by following the practices recommended in Lake States Aspen Report No. 5 (Seasoning of Aspen). Decay damage to aspen cabin logs can be reduced by following the handling practices recommended in Lake States Aspen Report No. 15 (Aspen for Cabin Logs). Decay damage to aspen fence posts and other aspen products during seasoning can be eliminated or reduced by peeling and open stacking to promote more rapid drying. The resistance of aspen to checking makes it possible to stack posts and other aspen products to promote rapid drying without danger of serious checking.

TREATING PROCESSES AND PRESERVATIVES

Whereas it is possible to minimize or eliminate decay losses in aspen products during seasoning by modifications in handling practices, the only method of insuring a reasonable service life or of preventing rapid deterioration of aspen products used under conditions favoring decay is through preservative treatment. As previously mentioned, there has been less experience with the treatment of aspen than with the treatment of most of the Lake States wood species used for fence posts, ties, mine timbers, and other products commonly given preservative treatment. Also, very little has been published on the treating of aspen and most of the information given here was obtained through discussion with operators of treating plants.

Pressure Treatment

At least five pressure-treating plants in Minnesota and Wisconsin have had experience with the pressure treatment of aspen ties, aspen bridge planking, mine timbers, and fence posts. Most of the experience has been with the Lowry and Rueping Empty-Cell Processes and with coal tar creosote, and zinc chloride has been used to a limited extent. Sawn ties incised on all four sides and hewn ties incised on the hewn surfaces and adzed and bored prior to treatment are reported to treat rather uniformly by the Lowry and Rueping Empty-Cell Processes, and no special difficulties have been reported. In general, the same is true for bridge planking and sawn mine timbers. In case of unincised sawn or hewn aspen ties, large fence posts, and round mine timbers, rather erratic penetration was reported. End penetration of preservatives was excellent, but radial penetration varied from 1/16 inch to 1 inch in the same piece. This variation in penetration of preservatives in different parts of the same piece constitutes one of the reasons why the preservative treatment of round aspen products is considered difficult. The presence of tyloses in both the sapwood and heartwood of large-tooth aspen has been suggested as a possible explanation for the irregular penetration of preservatives in wood of this species (C. H. Teesdale and J. D. Mac Lean, U. S. Dept. of Agr., Bulletin 606, 1918). The more uniform treatment of sawn aspen products can probably be traced to penetration through exposed end-grain on the sawn surfaces. This appears a logical explanation because most aspen lumber is cut from small logs, and there is abundant end-grain on the sawn surfaces associated with small knots and other defects. In case of incised material, penetration is uniform because incising makes tangential and longitudial penetration possible in addition to radial penetration.

Excellent penetration of coal tar creosote in small aspen posts (3-4 inches top diameter) was reported by one treating plant experimenting with this material. With larger posts, however, some difficulty was experienced in obtaining uniform penetration of the preservative.

Material to be given pressure treatment with creosote or other oil preservatives should be free from bark and at a moisture content below fiber saturation, 30 per cent. Better results are claimed in treating material at moisture contents of 15 to 25 per cent than drier material.

Hot-cold Bath Process

The hot-cold bath process (8) has been used experimentally and by a number of small commercial treating plants in the treatment of aspen fence posts and mine timbers. Coal tar creosote, water gas tar, oil solutions of pentachlorophenol, and zinc chloride have been used in this process. Both butt-treatment and full-length treatment by this process have been tried. In fence posts in particular, spotty or erratic penetration at the ground line, the critical area, has been common for large posts. Penetrations varying from 1/16 inch to 1 inch are not uncommon in the ground-line zone of individual posts. This is greater variation than is commonly encountered

with other hardwoods and far greater than for jack or red pine, for which penetration is usually very uniform and deep penetration is far more easily obtained. Excessive end penetration of preservative in aspen posts also results in waste of preservative because such end penetration rarely extends to the ground line, where it is most needed. A combination of hand incising of the ground-line area and treatment by the hot-cold bath process result in deep and uniform penetration at the ground line without excessive absorption of preservative in the butts. However, such incising is slow and expensive and has been used only experimentally.

For small aspen posts, 3-4 inches top diameter, a butt treatment by the hot-cold bath process may be all that is needed for posts used in the Lake States, but a light top treatment is good insurance against top rot and should be applied wherever possible. For larger posts, some top treatment is essential because of the danger of top rot. Top rot is common in larger posts of all non-durable species, whereas it is rather infrequent in smaller posts. This difference is probably due to the tendency of the tops of larger posts to retain moisture for long periods following heavy rains, thus favoring top rot. Smaller posts, on the other hand, appear to dry out so rapidly that there is less opportunity for top rot to develop.

Clean peeling and careful air seasoning appear to be as important in treating by the hot-cold bath process as for pressure treatment.

Non-pressure Processes

Cold-soaking in oil solutions of pentachlorophenol: Considerable experimental work has been done at the Forest Products Laboratory and at the University of Minnesota on the treatment of seasoned aspen posts by soaking in cold-oil solutions of pentachlorophenol (1). Treatment has been by soaking either full length or by butt treatment after air seasoning of clean-peeled posts.

The results with this process on aspen have been very disappointing and unsatisfactory when compared to results obtained on jack pine, red pine, and black ash. Penetration of preservative at the ground line has been found extremely variable, and rarely does it exceed 1/4 inch. In some posts the penetration, even after long periods of soaking, has been no more than 1/16 inch. Absorption of preservative solutions by posts may be entirely satisfactory, but most of the preservative is in the butts in butt-treated posts and in the butts and tops of full-length treated posts, with very shallow and unsatisfactory penetration at the critical ground line zone.

The process is simple, and pentachlorophenol is an excellent wood preservative, but the results obtained have been disappointing because of the poor and irregular penetration of preservative at the ground line, where treatment should be deepest. The service data available on aspen posts treated by this process with pentachlorophenol (Table 3) indicate that some posts may fail in 4 to 6 years, and that such failure is due to spotty or shallow penetration and not to any fault of the preservative.

Tire tube treatment with zinc chloride or chromated zinc chloride: A considerable number of aspen posts have been treated by this process, which is described in a statement prepared by the Forest Products Laboratory (4). The published information available indicates that zinc chloride, chromated zinc chloride, and other water-borne preservatives move rather rapidly through freshly cut green aspen posts when solutions of preservatives are applied to the butt ends by this process. Little is known regarding the quantitative distribution of preservatives in posts but the occurence of decay in the tops of some treated posts after 5 to 8 years in service indicates that in some posts, at least, distribution is not uniform.

The results of service tests indicate that posts treated by this process should last at least 10 years (Table 3). Although considerable decay has developed in many of the posts treated by this process in the 7 to 8 years that have elapsed since they were set, their condition indicates that most of them will have at least several added years of life.

The process is time-consuming and not well adapted to the treatment of large numbers of posts. Also, there is some question as to whether the results that can be obtained are any better than those obtained by treating with the same chemicals by a simpler and cheaper process, designated as the "butt-soaking process."

Butt-soaking treatment with zinc chloride or chromated zinc chloride: This process was first extensively tried at Clemson College, South Carolina on southern pine posts (6). The process consists of immersing the butt ends of freshly-cut unpeeled posts in concentrated solutions of zinc chloride or chromated zinc chloride placed in shallow vats, tanks, or drums. The concentrated solutions move into the posts by diffusion and possibly by capillarity. The quantity absorbed can be controlled to some extent by adjusting the concentration of the treating solution and period of immersion.

In rather extensive tests with this process at the University of Minnesota, it has been found that 27 per cent or 33 per cent solutions (3 or 4 pounds per gallon of water) of chromated zinc chloride are preferable to weaker solutions. By immersing the butts of freshly cut aspen posts in these solutions for two days and then reversing the posts and immersing the tops for one-half day, absorptions of ½ to 1½ pounds of the preservative per cubic foot of wood have been obtained (Table 1). The preservative is concentrated in the butts and tops immediately after treatment, but further distribution, sometimes rather uniformly throughout the posts, is obtained by setting the posts on their tops for two weeks to a month.

Table 1

Variation in absorption of chromated zinc chloride solutions by green aspen posts of the same lot when treated by the butt-soaking process

Post No.	Top Diameter	Treating Period		Absorption of CZC in lbs/cu.ft.
		Butt	Top	
	Treatment with a 27 per cent solution			
1	3.6	2 days	½ day	1.139
2	3.4	2 days	½ day	1.157
3	4.3	2 days	½ day	1.416
4	3.9	2 days	½ day	1.270
5	3.3	2 days	½ day	1.256
6	3.7	2 days	½ day	1.800
7	3.1	2 days	½ day	1.975
8	4.3	2 days	½ day	1.015
	Treatment with a 20 per cent solution			
1	4.6	2 days	½ day	.605
2	4.2	2 days	½ day	.630
3	4.6	2 days	½ day	.540
4	4.3	2 days	½ day	.544
5	3.9	2 days	½ day	.549
6	3.3	2 days	½ day	.851

Service records on aspen posts treated by this process are not available, but results should be similar to those obtained on aspen posts treated by the tire-tube method. Many problems connected with this treating procedure require additional work. Preliminary tests indicate that high concentrations of chromated zinc chloride do not injure the wood, but this point needs further study. Also, there appears to be considerable difference in the absorption of preservative by posts cut on different sites or at different times of the year (Table 2). The very low absorptions obtained for posts cut on a poor site near New Brighton, Minnesota are particularly disturbing. The necessity of using freshly cut posts or of removing discs from the ends of posts that have been cut for several days is a distinct disadvantage of the process. The low cost of the treating chemicals and simplicity of the treating process are advantages that give the process some promise for use by farmers in the Lake States.

Table 2

Variation in Absorption of a 27 per cent Chromated Zinc Chloride Solution by Green Aspen Posts of Different Lots When Treated by the Butt-Soaking Process

Date Cut	Source	Average Top Diameter	No. of Posts	Days Treating Period Butt	Days Treating Period Top	Ave. Absorption of preservative (CZC) lbs/cu. ft.
June 1947	Cloquet, Minn.	3.7	8	2	½	1.39
April 1947	New Brighton, Minn.	3.7	12	2	½	.15
Feb. 1947	Cloquet, Minn.	4.2	8	2	½	.77
Feb. 1947	Cloquet, Minn.	3.9	10	2	½	.99

Treatment by Steeping: Peeled aspen fence posts and mine timbers have been treated by steeping in zinc chloride and chromated zinc chloride. The process consists of soaking green peeled material in tanks of the preservatives, concentrations of 5 per cent being most commonly used (5). The preservatives penetrate by diffusion, and the soaking period is normally a week or longer. No published service records are available on mine timbers treated by this process, but one user of aspen mine ties steeped for 6 days in a 5 per cent solution of zinc chloride reported a life in excess of 10 years.

The process is slow and large tanks are required, but it has some application for mine timbers for which untreated aspen is not satisfactory and for which a service life of 10 to 12 years is all that is desired.

Treatment by the Osmose Process: A number of aspen fence posts have been treated by the Forest Products Laboratory with Osmotite and Osmosar (Table 3). These chemicals were applied in paste form to the surface of freshly peeled green posts and the posts bulk-piled and covered with a moisture-resistant paper for a period recommended by the manufacture of these preservatives. The preservatives penetrate the green posts by diffusion during the bulk-piling period and the posts can be set when removed from the pile or after seasoning.

As indicated by the results of service tests given in Table 3, aspen posts treated with these chemicals develop early decay, and the results are far inferior to those obtained with the same chemicals on pine posts. This difference in results on aspen and pine again points to lack of penetration in aspen as the probable cause of the rather inferior results obtained.

Treatment by Dry Salting: During the past two years more than four hundred peeled green aspen posts have been treated by the University of Minnesota by a process similar to the Osmose Process. This consists of applying a mixture of dry powdered copper sulphate and sodium dichromate to green, freshly peeled aspen posts as they are bulk-piled. The posts are given a half turn after the upper surface has been covered with the mixture of these chemicals, and the application is repeated to cover the remaining surface. This process permits concentration of the preservative at the ground line and top, where treatment is most important. Only enough preservative is applied to the remainder of the post to give it a uniform color.

This mixture of chemicals absorbs moisture from the wood very rapidly, and it is usually advisable to allow the peeled posts to surface-dry for a day or so to prevent excessive loss of chemicals by drainage. Although the chemicals react on the surface of the posts to form copper chromate, this material appears to be sufficiently soluble to penetrate the wood by diffusion. Leaching tests on treated wood indicate that the preservative is extremely resistant to removal once it has penetrated the wood.

Penetrations of 1/4 to 3/4 inch are normally obtained, and distribution is surprisingly uniform, considering the method of application. In posts treated to obtain an over-all retention of 1 pound of the preservative per cubic foot but with treatment concentrated at the ground line and top, analyses have shown that 5 to 6 pounds of preservative per cubic foot of treated wood may be present at the ground line.

In tests made to date, several mixtures of these chemicals have been tried:

(a) Copper sulphate 90 per cent and sodium dichromate 10 per cent
(b) " " 75 " " " " " 25 " "
" " 50 " " " " " 50 " "

About 100 of the posts treated with these chemicals by this process are now in service tests, but it is too early to predict whether or not the results will be better than those obtained with other chemicals applied by diffusion processes. The extreme resistance to leaching shown by the chemicals once they have penetrated the wood suggests greater permance than has been obtained with other water-borne preservatives, but the effectiveness of these chemicals when applied by dry-salting needs to be established through service tests.

Advantages of the method are its low cost and simplicity, no treating equipment being required. In a trial of the process during the summer of 1947, two men cut, peeled, and treated 200 small (3-4 inch top diameter) aspen posts in one day. With copper sulphate at $.07 and sodium dichromate at $.12 per pound, the cost of chemicals per post averaged $.08 when a 50-50 mixture was used, and the posts were treated to obtain a retention of approximately 1 pound per cubic foot. In addition to labor and chemicals there was a small added cost for moisture-resistant crepe paper, used in covering the bulk-piled posts.

Disadvantages of the process are its dirtiness and the difficulty of obtaining sodium dichromate. Powdered copper sulphate is available in most localities, but sodium dichromate must be obtained through large chemical companies.

The treated posts have a blue-green or brown color. Preliminary corrosion tests on wire staples and nails have shown that there is little danger of corrosion to wire or fastenings with this combination of chemicals. However, additional tests on this point are needed.

The process cannot be recommended for the treatment of aspen until service records are available, but it appears to have sufficient promise to merit additional investigation.

Treatment with "Treater Dust": About 20 years ago a number of aspen posts were treated by the University of Minnesota by applying "Treater Dust," or powdered white arsenic (3), to the fence post holes and around the posts as they were set. This treatment resulted in some increase in life of the posts but not enough to justify the cost. The average life of small untreated aspen posts in these tests was 3.5 years and for posts treated with "Treater Dust" it was 5.2 years.

Miscellaneous non-pressure treatments: Dry aspen posts have been treated by applying several brush coats of creosote to the butts. There are no service records on aspen posts treated in this manner, but experience with other species indicates that such treatment with a good grade of coal tar creosote should at least double the life of small aspen posts, or increase it from about 3 years to 5-6 years.

Brush and spray applications of clear oil solutions of pentachlorophenol have been applied to aspen cabin logs after the cabins have been erected. Except for the lower logs, which may become wet from rain dripping or splashing, decay is not a serious factor in cabin logs. Consequently, as far as prevention of decay is concerned, such applications have little value. However, such treatment seems to prevent darkening or discoloration of the logs. Untreated aspen logs, like the tops of aspen fence posts, soon take on a grey or grey-brown color, but logs and fence posts treated with light oil solutions of pentachlorophenol retain a much lighter and cleaner appearance. Whether this is due to the prevention by the preservative of growth of staining fungi and molds on the surface or to other factors is not known.

SERVICE RECORDS ON TREATED ASPEN

Practically all of the published service records available on aspen treated with different preservatives and by different processes are on fence posts. These records are summarized in Table 3.

Although most of these tests have not been established long enough to obtain average service lives, the condition of the posts when last examined is indicative of the effectiveness of the preservatives and treating methods.

Relatively few service records on aspen posts pressure-treated with coal tar creosote are available. The results on posts treated with this preservative in mixture with gas oil (25 per cent coal tar creosote and 75 per cent gas oil) indicate that aspen posts pressure-treated with this mixture or with other creosote-oil combinations should give good service (Table 3). Although this particular group of posts was given a rather heavy treatment, they were in excellent condition after 22 years of service. There are more service records on pressure-treated cottonwood than on pressure-treated aspen. Cottonwood posts given a good pressure treatment with coal tar creosote are known to give 20 to 25 years of service. The similarity in treating characteristics of aspen and cottonwood suggests that equally good results should be obtainable with pressure-treated aspen posts. Because of the greater uniformity in penetration obtainable with small aspen posts, more uniform results should be possible with smaller posts than with larger material. The results on posts given a pressure treatment with a 2.9 per cent solution of tetrachlorophenol in crank case oil (Table 3) indicate that aspen posts pressure-treated with oil solutions of the chlorophenols, particularly with pentachlorophenol, should given service similar to material treated with coal tar creosote.

All of the available service records on aspen posts treated by the hot-cold bath process are on full length treated material. After 10 years of service those posts treated with coal tar creosote by this process are still in excellent condition (Table 3). Because of the full-length treatment no top rot has developed. However, there is real danger of failure due to top rot in large aspen posts given only a butt treatment by the hot-cold process. As indicated previously, thorough butt treatment

of 3-4 inch aspen posts and a very light top treatment appear to be all that is needed because top rot does not develop to an important extent in small posts of nondurable species used in the Lake States. For larger posts, however, a good top treatment should be given in addition to butt treatment. This top treatment might consist of a few hours soaking in hot oil with the tops immersed to a depth of 6-12 inches.

The service tests on aspen posts treated by cold soaking in oil solution of pentachlorophenol (Table 3) have not run long enough to permit final conclusions, but the erratic and shallow penetration at the ground line zone, coupled with early failure of a number of posts, suggests that this treatment will not prove as satisfactory for aspen posts as for jack pine, red pine, and southern pine posts. More aspen posts have been treated by this process and are in service tests than for any other preservative or treating procedure. Consequently, we should have a good evaluation of the process in a few more years.

The results given in Table 3 on water-borne preservatives applied by various processes reflect not only the variability in absorption of preservative that appears to be characteristic for aspen but the lack of resistance to leaching inherent in most of these preservatives. It is questionable whether a service life of more than 10-12 years can be obtained for aspen products treated with these water-borne preservatives even though good absorption and distribution are obtained. Treatment of aspen with these water-borne preservatives appears to be advisable only for farm use and possibly for some types of mine timbers. Since treatment with these preservatives may increase the service life of aspen fence posts to 10 years or somewhat longer, as compared to 3-4 years for untreated posts, the use of these water-borne chemicals and various non-pressure treating processes can be very economical and advantageous to the farmer owning aspen timber of post size.

Service records on aspen ties

No published service records are available on treated aspen ties. One Lake States railroad installed a large number of pressure-creosoted aspen ties in one of their tracks 15 years ago and has observed these ties since that date. The ties were hewn on two faces and most of them were very large. The ties were not adzed or bored prior to treatment, and this fact may account for much of the difficulty that has been experienced with them. Absorption of about 8 pounds of a good grade of coal tar creosote per cubic foot was obtained, and increment-borer measurements indicated that penetration was excellent on the unslabbed surfaces but was more spotty and not as deep on the slabbed surfaces. After 15 years of service these ties have an excellent surface appearance. They are very free from checks and there is no outward evidence of deterioration. However, at the time of examination (1947), many of the spikes were loose. This loosening of spikes has been prevalent for these ties for a number of years and is attributed partly to the poor spike-holding quality of aspen and partly to the development of decay in the interior of the ties around the spike holes. The wood around the loose spikes

below the treated zone was soft and appeared to be decayed in a number of ties. Had these ties been bored and adzed prior to treatment there would have been little chance of decay developing around the spikes, and the difficulty with spike-loosening undoubtedly would have been less serious.

Several other railroads have used treated aspen ties in the past. Their greatest objection to these ties was not their durability or service lives, but the difficulty experienced in seasoning and with spike loosening. In the opinion of these users, aspen ties that are adzed and bored prior to treatment and are given pressure treatment with a good grade of coal tar creosote should have as good service lives as similar cottonwood ties, for which service lives of 20 to 30 years have been obtained (7). The problem of spike-loosening is less important with heavier tie plates and the adoption of adzing and boring prior to treatment as uniform practice, but it is still important on curves. Aspen is known to have lower nail-holding properties than woods of similar density, but whether this difference is sufficient to rule out a greater use of aspen for ties is not certain. The similarity of aspen and cottonwood in most properties, including nail-holding, indicate that it should perform as well as the latter species when given the same treatment and used under the same conditions.

Service records on aspen mine timber

No published service records are available on treated aspen mine timbers, but the experience of several users indicates that when properly treated this wood performs about as well as most of the hardwoods used. In general, however, results appear to be inferior to those obtained with jack pine and other conifers, probably because of the greater difficulty of obtaining uniform treatment of aspen.

Service records on treated aspen bridge planking

Pressure-creosoted aspen bridge planking used in secondary bridges has given excellent results in Minnesota. Several reports were obtained of planking that was in good condition after 10 years of service. The resistance of aspen to checking and to wear, under conditions where only light traffic is involved, combined with the excellent treatment that can be obtained with sawn aspen products, makes pressure creosoted aspen bridge planking a very satisfactory material.

Table 3. Service Tests on Aspen Fence Posts Treated with Different Preservatives by Several Processes

Agency Making Test	Posts Set at	Preservative	Absorption lbs. per cu. ft.	Number Set	Top Diameter (inches)	Date Set	Date Last Examined	Condition Decaying	Condition Failed	Average Service Life (years)
Treated by the Tire Tube Method										
For. Prod. Lab.	Madison, Wis.	Zinc Chloride	.14 to 1.88	45	4-8	1937	1945	42	2	--
For. Prod. Lab.	Madison, Wis.	Chromated Zinc Chloride	.64 to 1.35	28	4-8	1937	1945	28	0	--
For. Prod. Lab.	Madison, Wis.	Sodium Chromate	.22 to 1.20	3	4-8	1937	1945	1	2	--
For. Prod. Lab.	Madison, Wis.	Copper Sulfate	.12 to .54	17	4-8	1937	1945	13	1	--
Lake States For. Exp. Sta.	La Crosse, Wis.	Zinc Chloride	.5 to .75	15[1/]	4-7	1938	1945	--	0	--
Lake States For. Exp. Sta.	La Crosse, Wis.	Zinc Chloride	.5 to .75	15[2/]	4-7	1938	1945	--	0	--
Treated by Diffusion Process - Chemical in Paste Formed Applied to Peeled Green Posts as Recommended by Osmose Corporation										
For. Prod. Lab.	Madison, Wis.	Osmosar	.29	16	5-7	1936	1946	16	14	6.4
For. Prod. Lab.	Madison, Wis.	Osmotite	.23	7	5-7	1936	1946	7	6	6.6
For. Prod. Lab.	Drummond, Wis.	Osmosar	.29	49	5-7	1936	1946	45	18	--
For. Prod. Lab.	Drummond, Wis.	Osmotite	.83	75	5-7	1936	1946	51	12	--
Treated with Oil Solutions of Pentachlorophenol by Cold Soaking -- Treating Time Given in Preservative Column										
For. Prod. Lab.	Oregon, Wis.	8 hrs. - full length	2.8[3/]	9	4	1943	1946	8	3	--
For. Prod. Lab.	Oregon, Wis.	24 hrs. - full length	3.4[3/]	9	3.7	1943	1946	4	0	--
For. Prod. Lab.	Oregon, Wis.	48 hrs. - full length	4.2[3/]	9	3.7	1943	1946	3	0	--
For. Prod. Lab.	Oregon, Wis.	96 hrs. - full length	5.1[3/]	9	3.8	1943	1946	1	0	--
For. Prod. Lab.	Oregon, Wis.	168 hrs. - full length	5.5[3/]	8	3.5	1943	1946	2	0	--
U. of Minn.	Cloquet, Minn.	18 hrs.-butt, 6 hrs.-top	4.6[3/]	30	3-5	1942	1946	-	0	--
U. of Minn.	Cloquet, Minn.	40 hrs.-butt, 8 hrs.-top	3.5[3/]	30	3-5	1942	1946	-	0	--
U. of Minn.	St. Paul, Minn.	18 hrs.-butt, 6 hrs.-top	3.0[3/]	20	3-5	1942	1946	-	4	--
U. of Minn.	St. Paul, Minn.	40 hrs.-butt, 6 hrs.-top	2.8[3/]	20	3-5	1942	1946	-	2	--
U. of Minn.	Waseca, Minn.	18 hrs.-butt, 6 hrs.-top	2.9[3/]	20	3-5	1942	1946	-	2	--
U. of Minn.	Waseca, Minn.	40 hrs.-butt, 6 hrs.-top	3.4[3/]	20	3-5	1942	1946	-	0	--
U. of Minn.	Cloquet, Minn.	Untreated	None	30	3-5	1942	1946	-	30	2.8
U. of Minn.	St. Paul, Minn.	Untreated	None	20	3-5	1942	1947	9	11	3.4
U. of Minn.	Waseca, Minn.	Untreated	None	20	3-5	1942	1946	3	17	3.4
Lake States For. Exp. Sta.	La Crosse, Wis.	Untreated	None	15	4-7	1938	1941	15	15	2.3
Hot-Cold Bath										
For. Prod. Lab.	Madison, Wis.	Coal Tar Creosote (Full length treatment)	9.4	10	4-5	1936	1947	0	0	--
For. Prod. Lab.	Drummond, Wis.	Coal Tar Creosote (Full length treatment)	11.4	25	3-5	1936	1946	0	0	--
For. Prod. Lab.	Madison, Wis.	Zinc Chloride (Full length treatment)	1.32	64	4-8	1937	1945	63	0	--
Pressure Treatment										
For. Prod. Lab.	Madison, Wis.	Tetrachlorophenol	7.5[4/]	10	5-7	1936	1947	6	0	--
For. Prod. Lab.	Drummond, Wis.	Tetrachlorophenol	8.2[4/]	22	3-6	1936	1946	3	0	--
For. Prod. Lab.	Madison, Wis.	25% coal tar creosote and 75% gas oil	16.1	20	5-7	1916	1938	0	0	--

1/ Posts set with mark up.

2/ Posts peeled before setting.

3/ Absorption in pounds of 5.0 solutions of pentachlorophenol in fuel oil or kerosene.

4/ 2.9 percent solution of tetrachlorophenol in crank case oil.

Dashes (--) indicate that records were not taken or are not available.

Summary and Recommendations on The Preservative Treatment of Aspen

Because aspen possesses no natural durability, all aspen products used in contact with the soil decay rapidly, and such products as untreated aspen fence posts rarely last more than 3 to 4 years. When aspen is used for sills of buildings, bridge planking, and the lower logs of log cabins, where the products are not in contact with the soil but may become moist and remain moist for considerable periods, deterioration by decay may also develop rapidly.

Aspen products to be given preservative treatment with coal tar creosote or with oil solutions of pentachlorophenol and copper naphthenate must be cleanly peeled and free from inner bark. All aspen products to be given treatment with any of these oil solutions must be well air-seasoned. To avoid possible losses from decay during seasoning, aspen ties, fence posts, mine timbers, and planking should be openly piled to promote rapid drying. Aspen does not check as badly as the heavier hardwoods and can be more openly stacked without danger of serious checking.

Aspen planking, sawn ties, and sawn mine timbers can be readily treated with coal tar creosote by the Rueping and Lowry Empty-Cell pressure-treating processes. The same is true for ties that are incised, adzed and bored prior to treatment. Although there has been less experience with the treatment of these aspen products with other preservatives, it is logical to assume that similar results could be obtained with oil solutions of pentachlorophenol or copper naphthenate applied by the empty-cell processes, and with water-borne preservatives, such as zinc chloride, chromated zinc chloride, and various proprietary compounds, when applied by the full-cell pressure-treating process. In case of large round aspen products, such as fence posts and mine timbers, some difficulty has been encountered in obtaining uniform penetration by the pressure treating processes.

The limited experience reported on the treatment of aspen products by the hot-cold bath process indicates that fairly satisfactory treatment can be obtained in case of sawn products and small round fence posts, but that penetration may be spotty in critical areas of large round posts (over 5 inches in top diameter) and other large round aspen products. The published information indicates that only coal tar creosote and zinc chloride have been applied to aspen by this process, but it is logical to assume that suitable oil solutions of pentachlorophenol and copper naphthenate could be applied with similar results. Small aspen posts (3-4 inches in top diameter) do not benefit as much from top treatment as large posts (5 inches and over in top diameter), but some treatment to protect the tops from top rot is advisable. When given thorough treatment by pressure or the hot-cold bath process, aspen posts with 3-4 inch top diameters should be adequate for all fencing uses except corners, and the use of larger posts is not recommended.

A considerable number of seasoned aspen fence posts have been treated with oil solutions of pentachlorophenol by cold-soaking. The erratic and shallow penetration obtained with this process to date indicates that it cannot be satisfactorily used with this species unless some cheap and simple method of incising the ground line area can be found.

Green aspen fence posts and mine timbers have been treated with water-borne preservatives, such as zinc chloride, chromated zinc chloride, and several proprietary compounds, by the steeping, the tire-tube, the butt-soaking, and several diffusion processes. Although treatment with water-borne preservatives by all of these processes is not always uniform and the results in many cases have been disappointing, the average service life of aspen products can be increased sufficiently through such treatments to warrant the consideration of these processes for the treatment of posts by farmers and for the treatment of some types of mine timbers.

Increased service or resistance to decay can be achieved by brush-coating dry aspen lumber, fence posts, or other aspen products with several coats of coal tar creosote or with oil solutions of pentachlorophenol and copper naphthenate. Such treatment is suggested when aspen must be used for farm building items subject to decay and when no more thorough method of treatment can be employed. The treatment of aspen cabin logs with several brush coats of a clear oil-solution of pentachlorophenol keeps the logs from darkening to the same extent as untreated logs.

Most of the published service records on pressure- and hot-cold bath-treated aspen products are on fence posts treated with coal tar creosote. These records indicate that service lives of over 20 years or service similar to those obtained with other woods treated with the same preservative can be obtained for aspen given thorough treatment by these processes. On the basis of the results obtained on aspen posts treated with a crank-case oil solution of tetrachlorophenol, and the generally recognized superiority of pentachlorophenol over tetrachlorophenol, results similar to those obtained with coal tar creosote should be obtainable on aspen products treated with suitable oil solutions of pentachlorophenol by pressure or hot-cold bath treating processes.

The service records on aspen products treated with water-borne preservatives indicate that service lives of at least 10 years should be obtainable for well treated products. Although some decay may develop during this period because of leaching of the preservatives, the available service records indicate that service records of 10 or more years usually can be expected of products well treated with water-borne preservatives.

Problems Associated With the Preservative Treatment of Aspen that Need Study

Although practically every aspect of the preservative treatment of aspen needs study, the following problems particularly need attention:

1. The air seasoning of aspen ties, mine timbers, fence posts, and other aspen products. Can the serious losses from decay now frequently encountered when following stacking practices worked out for other species be reduced by more open stacking without incurring serious checking losses?

2. Reduction of end absorption in treatment by the hot-cold bath process. Can excessive absorption of creosote and other preservatives in the butts of aspen, where it does little good, be reduced by end coatings or other methods?

3. Size of aspen fence posts. What size aspen post is needed to provide adequate strength and over-turning resistance, provided the post receives an effective preservative treatment?

4. Spike holding properties of aspen ties. Is this an important factor when ties are incised, adzed, and bored prior to treatment and when new types and larger tie plates are used?

5. Cold-soaking in oil solutions of pentachlorophenol. Can anything be done to improve the ground-line penetration in seasoned aspen posts treated by this simple and relatively low cost process, which is so promising for many other species?

6. Creosote-petroleum mixtures. To what extent can coal tar creosote be diluted with the cheaper petroleum oils and still produce effective treatment by the pressure and hot-cold bath treating processes?

7. Service records on treated aspen products. The service records on aspen treated with water-borne preservatives are completely inadequate, and much additional material should be installed in service tests. The same is true for aspen treated with oil preservatives by the pressure and hot-cold bath treating processes.

8. Treatment by simple diffusion processes. Much work is needed on the simple diffusion-treating process described in this report. Other chemicals and combinations of chemicals should be tested in addition to further tests on the chemicals already tried.

9. Butt-soaking treatment. Chemical analyses are needed on aspen posts treated by this process to determine how uniformly preservatives are distributed. Also, tests should be made on aspen posts cut from various sites at different times of the year to establish the variability that may be encountered.

10. The effect on strength of high concentrations of water-borne preservatives. Added tests are needed to determine whether the high concentrations of chromated zinc chloride in the butt-soaking process seriously affect strength.

References

1. Blew, J. C. Treating wood in pentachlorophenol solutions by the cold-soaking method. Forest Products Laboratory Mimeograph R1445. 1948.

2. Schmitz, H. and L. W. R. Jackson. Heartrot of aspen. University of Minnesota Agricultural Experiment Station Technical Bulletin No. 50. 1927.

3. Schmitz, H. Unpublished report in files of Division of Forestry, University of Minnesota. 1936.

4. Wirka, R. M. Tire-tube method of fence-post treatment. Forest Products Laboratory Mimeograph R1158. 1945.

5. Wirka, R. M. Preservation of timber by the steeping process. Forest Products Laboratory Mimeograph R621. 1943.

6. Circular 262, Clemson Agricultural College, Clemson, S. C.

7. Proceedings of the American Wood Preservers' Association, Tie Service Records, 1939, 1942, and 1943.

8. Selecting a suitable method for treating fence posts. Forest Products Laboratory Mimeograph No. R1468. 1946.

LAKE STATES ASPEN REPORT NO. 20

MARKETING OF ASPEN

BY
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PROCESSED BY
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LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (*Populus tremuloides*) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up to date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

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1	Aspen Properties and Uses
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6	Aspen Lumber Grades and Characteristics
7	Mechanical Properties of Aspen
8	Machining and Related Properties of Aspen
9	Aspen Lumber for Building Purposes
10	Aspen for Containers
11	Aspen for Core Stock
12	Small Dimension and Other Industrial Uses of Aspen
13	Aspen for Veneer
14	Aspen for Pulp and Paper
15	Aspen for Cabin Logs
16	Aspen for Excelsior
17	Aspen Defiberization and Refining of Product
18	Chemical Utilization of Aspen
19	Preservative Treatment of Aspen
20	Marketing of Aspen
21	Possibilities of Managing Aspen

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Forestry Agent, Chicago & North Western Railway System, St. Paul 1, Minn.

REPORT NO. 20

MARKETING OF ASPEN

By
Zigmond A. Zasada, Forest Economist
Lake States Forest Experiment Station 1/

INTRODUCTION

The Lake States timber industry did a creditable job of producing and using considerable volumes of aspen during the war years. At that time it was shown that aspen could fill a variety of uses satisfactorily. However, improved marketing techniques are needed if present aspen stands are to be fully and profitably utilized. The aim of this paper is to call the attention of owners and producers of aspen to some of the points to be considered to improve marketing.

It is more difficult to market aspen than most other Lake States timber species. One limiting factor in its use is its small size. Even under optimum growth conditions, aspen does not attain the size of the virgin pines and hardwoods of the Lake States. On many sites aspen never reaches sawlog size. This, together with the common light stand density, often prevents it from being harvested economically under present logging and milling methods used in virgin stands of other Lake States species. Its small size limits the amount of high-grade lumber it yields. The lumber trade has built up a prejudice against aspen because of low interest in harvesting it, shortage of accurate information on this species, misuse of the lumber, and lack of any great supplies.

KNOW YOUR PRODUCT

A prerequisite to good marketing is to know the good points as well as the limitations of the species concerned. The reports sponsored by the Lake States Aspen Committee can acquaint producers and users with the qualities of this wood, indicating where and how it can best be used. Further research and experience are needed to promote better marketing of aspen.

SALE OF STANDING TIMBER

The aim of timber owners is to market their standing timber at a profit. To do this, potential buyers must be informed of the timber supply available, its location, quantity, and quality. Although forest survey figures for the Lake States show that there is a large acreage and volume of aspen, there is little information as to exact location and

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1/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota, University Farm, St. Paul 1, Minnesota.

availability of supplies for a specified period. Information is needed, on at least a county basis, as to the extent and quality of aspen stands, before industries which could use aspen can become interested.

It is important that owners of aspen timber recognize that aspen develops into a tree suitable for sawlogs and veneer logs on good sites, whereas on poorer soils maximum tree size and life span of aspen decrease. In many locations, aspen will not even yield merchantable products. Also, much aspen is harvested before it attains its highest value. Furthermore, much mature aspen goes to waste because the owners are not familiar with the growth characteristics of the species.

Many forest owners could make profitable sales by furnishing prospective buyers with the following type of information on their timber:

1. The amount of timber in board feet or cords, and exact area involved.

2. Kind of timber, its quality, and size. In aspen, size is an important selling factor because larger trees yield the higher grades.

3. Location of timber, distance from town, railroad siding, and wood-using plant.

4. Accessibility - highways, woods roads, and trails which pass through or near the timber tract.

Forest owners who can furnish the above information are in a good position to make a sale. Sellers inexperienced in timber marketing should contact their local forester as to current prices and outlets for aspen.

Aspen stumpage is usually purchased by local loggers, timber brokers, and nearby wood-using industries such as sawmills, paper mills, veneer plants, etc.

Sales of stumpage or converted products should be covered by written agreements between the buyer and seller, with at least one witness. Such a contract will enable both parties to avoid many misunderstandings that may arise. (See sample contract form in appendix.)

SALE OF ROUGH PRODUCTS

Aspen is usually converted into rough products for sale as sawlogs, box bolts, pulpwood, veneer bolts, short logs, excelsior wood, tie cuts, cabin logs, cooperage stock, posts, or fuelwood. Every manufacturing plant has its own specifications for these products. Loggers should obtain these specifications and use them in cutting timber so as to get the highest value.

The marketing of aspen begins at the tree. Money can easily be lost by improper felling and log making. The operator should know, before cutting operations begin, the kind of products he is after. His cutters should be informed of specifications for all products to be harvested. Cutters should be trained and supervised to turn out products according to specifications. Cutting scant lengths may eliminate a high-priced product or make the logs worthless. Excess log lengths, on the other hand, not only result in waste of timber, but also a waste of time in manufacturing.

The present widespread practice of cutting aspen into 100-inch log lengths does not always result in getting the most value out of the timber for lumber, and limits the use of the lumber produced. To get maximum quality out of a tree, its merchantable length should determine the length of logs to be cut. In doing this, operators should take into consideration the clear portion of the tree as distinguished from the defective portion. Crooked trees should be cut so as to eliminate crook as far as possible.

Aspen lumber offers possibilities for use in building construction. Where such a market exists, loggers should cut logs which will provide a balanced stock of building lumber items. This means working up random length logs of 8-foot, 10-foot, and 12-foot sizes.

Aspen loggers have the problem of timing their operations to fit in with the use of the wood at the manufacturing plant. Rough aspen products going into lumber, mechanical pulp, wood fibre, excelsior, and veneer are wanted in green condition. Plants manufacturing these products expect to use the wood soon after it is received. When it is necessary to stock-pile aspen, it is usually stored for only a few months. For stock-piling, winter-cut wood is preferred to that cut in the summer. Aspen is a highly perishable product in log form. In selling aspen in this partly finished form, the forest owner and logger should be certain of his market. Aspen logs deteriorate rapidly in summer, and may be valueless to the producer if stored too long.

Peeled aspen is needed for pulpwood and excelsior wood. The usual peeling season for aspen lasts about three months in the spring. The peeled aspen market is seldom filled, and production for this market is not as great a risk as for unpeeled material. When suitable equipment is developed for peeling aspen, operators will have a wider market for their output, regardless of cutting season.

In many parts of the Lake States there is now a varied market for aspen. Such demand includes use as pulpwood, sawlogs, fibre wood, and veneer bolts. Therefore it may pay the timber owner or logger to market his aspen logs according to size, the small logs going into pulpwood and fibre bolts, and the large logs into veneer logs and sawlogs. However, before he "skims off" his best stock, the owner should make certain that he can sell the remainder at a fair price. Also, if the owner plans on an integrated operation, producing tie bolts, veneer logs,

sawlogs, and pulpwood, he should be sure that making all these products will bring him more money than if he were to make only one product.

Aspen is at a disadvantage in comparison with many other tree species because, from the standpoint of good forest management, it should be clear-cut when mature. At that time all trees should be cut regardless of size. This is necessary in order to start another crop of aspen. This type of cutting produces a volume of small wood suitable only for pulpwood, excelsior wood, or fibre bolts, for which there is only a limited market. On the other hand, full utilization yields a greater production per acre and cuts logging costs.

Wood manufacturing plants using aspen usually buy rough aspen direct from the loggers. Some of these concerns buy the stumpage and contract the logging to individuals living in the vicinity of the timber. Plants securing rough products from a long distance usually buy through a timber wholesaler.

In some instances small producers have formed marketing cooperatives to sell their logs. Such organizations give the producers a larger volume of timber for sale and can often secure them better prices than if they marketed separately.

SALE OF ASPEN LUMBER

A large volume of aspen is marketed in the form of lumber for boxes and crating, for juvenile and painted furniture, novelties, bee supplies, and a variety of other wooden articles. The building industry, through retail yards and contractors, is now using aspen lumber to a limited extent.

Because most lumber is sold a long distance from the mill and in a variety of ways, it is important to the sawmill man that he understands how lumber is marketed and what is involved in the marketing transactions. Wood-using plants in the timber supply area may buy their lumber from a sawmill man or from a wholesaler, depending on which can supply his needs more efficiently and at lower cost. Lumber users located a long way from sawmills usually will buy lumber from wholesalers or commission men.

More attention should be given to the manufacture and methods of distribution of aspen lumber if it is to hold its expanded markets and obtain wider use. Some lumber users have objected to introducing aspen lumber into their plants because they have not been able to obtain it in the form they want. Aspen has been sold largely as rough lumber, ungraded, often not seasoned, and many times mis-manufactured. It has been difficult to buy aspen lumber in a continuous reliable supply. Accordingly it has often been more costly for the consumer to use aspen than competing species.

To promote the marketing of aspen, the small sawmill man must make good lumber. Too much of the present aspen lumber produced by small sawmills is not sawed accurately, and is poorly edged and trimmed. Poor manufacture is wasteful and costly. Most important, poorly manufactured lumber is not attractive and lacks sales appeal.

The quality of aspen lumber can be improved mainly by proper sawing. Sawmill men should acquaint themselves with aspen grading rules. The sawmill man can be a great help or a great liability in improving the marketing of aspen, depending on his ability to turn out good grades of accurately cut lumber.

The seasoning, grading, and preparation of aspen lumber for specific uses may be beyond the means of the small sawmill man, and he may have to sell his lumber to a large sawmill, wholesaler, or concentration yard that will put it in proper condition for the market. Also, proper seasoning of lumber is often overlooked. Proper kiln drying of aspen lumber will provide a wider market in many specialized lumber uses. Piling is often carelessly done in the seasoning and handling of aspen lumber. As lumber supplies increase, buyers will be more insistent on getting properly seasoned lumber.

Grading of lumber is important to better marketing. In the past, very little aspen has been sold on a graded basis. Both the hardwood and softwood grading rules make provisions for the grading of aspen lumber. Lumber that is graded can be sold for specific uses and can be marketed according to its characteristics and qualities. Grading recognizes that some uses require better lumber than others. Lack of grading has kept aspen out of many industries. Several buyers have been interested in using aspen, but could not find anyone who could supply graded lumber.

The marketing of aspen could be improved if the lumber were better finished. Cut to size dimensions, its manufacture into siding, moulding, and similar items offers possibilities. Special markets often result in the saving of considerable material and help the users to reduce costs Understanding the market needs and supplying them with properly manufactured lumber will result in wider use of aspen.

It has been demonstrated by some producers that aspen lumber and products can be sold successfully if well manufactured and if direct contacts are made with the consumer to point out the excellent technical qualities of the wood for specific uses.

Increased advertising, trade promotion, and research activities by the Lake States Timber Industry, its trade associations and landowners can expand the lumber markets for aspen.

SUMMARY

Marketing of aspen is a problem confronting the timber industry and most forest landowners in the Lake States. The sooner action is taken on this problem, the sooner it will be solved. Aspen products are at a disadvantage with other species because of early prejudices due to poor manufacture and a tendency to underrate the wood. Aspen products are costly because their production has been left mostly to small operators. Any improvement in logging or lumbering of aspen which will lower costs can improve its position in competition with other species and materials.

Aspen is adaptable to many uses. It must, however, be properly manufactured, seasoned, and graded for these uses. Aspen should not be recommended for use where it is less well adapted than other species.

The producers of aspen are in good position to study its properties and learn how it works out for various uses. Continual handling of aspen and consultation with people who use it will give aspen producers much practical knowledge and help them in their marketing problems.

The establishment of concentration yards and lumber processing plants upon which users can depend for continuous supplies of well manufactured lumber will increase the use of aspen.

Well planned advertising and trade promotion by timber producers and lumber associations to publicize the true properties and uses of aspen will help expand aspen markets.

APPENDIX

Sample Timber Sale Agreement 2/

_____, _____, of _____, _____, hereinafter
(I or we) (Name of Purchaser) (Post Office) (State)
called the purchaser, agree to purchase from _____ of
(Seller's Name)
_____, _____, hereinafter called the seller, the designated
(Post Office) (State)
trees from the area described below.

I. Description of Sale Area:
(Describe by legal subdivisions, if surveyed, and approximate, if not

_____

_____

II. Trees Designated for Cutting: (Cross out A or B -- use only one clause.)

A. All _____ trees marked by the seller, or his
(species)
agent, with paint spots below stump height; also dead trees of the same species which are merchantable for _____.
(Kind of forest products)

B. All _____ trees merchantable for _____ (kind of forest
(species)
products) which measure _____ inches or more outside the bark at a point not less than 6 inches above the ground; also other _____ trees marked with paint
(species)
spots below stump height by the seller or his agent.

III. Conditions of Sale:

A. The purchaser agrees to the following:

1. To pay the seller the sum of $_____ for the above-described trees and to make payments in advance of cutting in amounts of at least $_____ each.

2/ Sample from U.S.D.A. Bulletin 1989, "Managing the Small Forest." 1947. Pages 60 -61.

2. To waive all claim to the above-described trees unless they are cut and removed on or before_____. (date)

3. To do all in his power to prevent and suppress forest fires on or threatening the sale area.

4. To protect from unnecessary injury young growth and other trees not designated for cutting.

5. To pay the seller for undesignated trees cut or injured through carelessness at the rate of $_____ each for trees measuring 10 to_____ inches in diameter at stump height and $_____ each for trees _____ inches or over in diameter.

6. To repair damage caused by logging to ditches, fences, bridges, roads, trails, or other improvements damaged beyond ordinary wear and tear.

7. Not to assign this agreement in whole or in part without the written consent of the seller.

B. The seller agrees to the following:

1. To guarantee title to the forest products covered by this agreement and to defend it against all claims at his expense.

2. To allow the purchaser to use unmerchantable material from tops of trees cut or from trees of_____species for necessary logging improvement free of charge, provided such improvements are left in place by the purchaser.

3. To grant the freedom of entry and right-of-way to the purchaser and his employees on and across the area covered by this agreement and also other privileges usually extended to purchasers of stumpage which are not specifically covered, provided they do not conflict with specific provisions of this agreement.

C. In case of dispute over the terms of this agreement we agree to accept the decision of an arbitration board of three

selected persons as final. Each of the contracting parties will select one person and the two selected will select a third to form this board.

Signed in duplicate this_____ day of _____ , 19___.

_____ _____
(Witness) (Purchaser)

_____
(Witness)

_____ _____
(Witness) (Seller)

_____
(Witness)

LITERATURE CONSULTED

(1) Cahall, R. R.

1947. Sawmilling practices that pay. Southern Pine Inspection Bureau, New Orleans, La., Bulletin. 107 pp.

(2) Garland, Hereford

1947. Utilization of aspen. A Problem Analysis. Michigan Dept. of Economic Development. Forest Products Research Publication No. 7. 23 pp.

(3) Muller, Joseph L.

1945. Establishing and operating a small sawmill business. U. S. Dept. of Commerce Bulletin. Industrial Series 20. 154 pp.

(4) Rees, Louis W.

1947. Aspen lumber for building purposes. Lake States Aspen Report No. 9. 11 pages, mimeo.

(5) Zasada, Zigmond A.

1948. Aspen lumber grades and characteristics. Lake States Aspen Report No. 6. 9 pp., mimeo.

(6) Zehngraff, Paul.

1947. Possibilities of managing aspen. Lake States Aspen Report No. 21. 23 pp., mimeo.

LAKE STATES ASPEN REPORT NO. 21

POSSIBILITIES OF MANAGING ASPEN

BY
PAUL ZEHNGRAFF
LAKE STATES FOREST EXPERIMENT STATION

JUNE 1947

PROCESSED BY
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

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Superior Wood Products, Inc., Duluth 2, Minn.
Forestry Agent, Chicago & North Western Railway System, St. Paul 1, Minn.

REPORT NO. 21

POSSIBILITIES OF MANAGING ASPEN IN THE LAKE STATES1/

By
Paul Zehngraff, Silviculturist
Lake States Forest Experiment Station2/

INTRODUCTION

The management of aspen or popple (Populus tremuloides) has received little attention in the past, largely because of the former abundant supply of other and more valuable tree species in the Lake States. Because of a rapidly expanding market for all forest products during the past decade, particularly during the war, the attention and ingenuity of industry have turned toward the use of aspen. As a consequence, aspen has now become one of the important pulpwood species in the Lake States, and is used for many other products. That it will retain its place for some time to come seems quite certain in view of its large acreage, its aggressiveness, and new uses which are constantly being found. For this reason, there is need for information on the possibilities of managing aspen as a forest crop.

ACREAGE AND VOLUMES

The aspen type constitutes nearly 40 percent of the total commercial forest area in the Lake States. According to the latest (1945) statistics, there are 19,858,000 acres of commercial aspen type in the region. Of this, 6 percent is in the sawlog-size class. Pole stands cover 18 percent. The remaining area is restocking and denuded land. (Details of availability and supply of aspen are found in Report No. 2 of this series.)

By comparing the 1945 volumes with those of 1936 (table 1), it is found that the quantity of aspen available for use has increased considerably during the last decade.

1/ Although the experimental data presented in this paper were collected in Minnesota, it is believed that many of the recommendations may be applied fairly generally to aspen areas in the Lake States.

2/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota, University Farm, St. Paul 1, Minnesota.

Table 1.- Volumes of standing aspen in the Lake States

Year	Total volume	Merchantable volumes	
		Pulpwood	Saw timber
	Millions of cubic feet	Thousands of cords	Millions of board feet
1936	3,135	10,371	4,127
1945	4,360	17,300	6,380
Increase in 10 years	39%	67%[1]	55%[1]

1/ The high increase is due partly to growth and partly to closer utilization practices taken into account in the later statistics.

DEMANDS

Aspen in the Lake States is used primarily for box lumber, pulpwood, excelsior, and match stock,3/ and to a lesser extent for construction lumber, interior finish, flooring, furniture manufacture, veneer, and novelties. Through the defiberizing method of producing coarse-fiber aspen, it shows promise for additional uses.

Despite its wide variety of uses, the best available information (6) indicates that of a total annual growth of 408 million board feet, only 40 percent is being used at present. Of the total annual cubic volume growth, the annual drain is only 25 percent. Thus the demand, especially for small or low-grade products, is still considerably below the actual growth.

CHARACTERISTICS OF ASPEN

THE SPECIES

Aspen as referred to in this paper includes primarily the quaking aspen (Populus tremuloides). The big-tooth aspen (Populus grandidentata) is frequently found in the same stand, and the properties of both species are so closely related that for commercial purposes they are seldom separated. Their characteristics and requirements are sufficiently similar to permit like treatment in management. The quaking aspen is by far the more common. It is distinquished from the big-tooth aspen primarily by its lighter bark and smaller leaves.

3/ See Report No. 1, "Aspen Properties and Uses," and other reports in this series for detailed uses of aspen.

SOIL REQUIREMENTS OF ASPEN

Although aspen is found on a wide variety of soils, it reaches its best development on soils that are porous, loamy, humic, and rich in minerals, especially calcium. It prefers moist but well-drained soils, and develops poorly on dry, sandy soils and on stiff, poorly aerated clay soils. On poorly drained soils decay sets in early.

Despite the fact that aspen springs up on all kinds of soils, it is one of the most sensitive species in regard to site requirements. On sites well-adapted to aspen, it develops into a good tree; on sites poorly adapted, it is short and scrubby and decays at an early age. A large portion of the present aspen acreage, therefore, will yield commercial products only under considerably improved utilization practices. The bigtooth aspen is probably less exacting in its soil requirements, and is often found growing fairly well on the poorer sites.

Of the 19.9 million acres of commercial aspen type in the Lake States, it is estimated by the Forest Survey that 15 percent is on good sites, 54 percent on medium sites, and the remaining 31 percent on poor sites. Only the good sites may be expected to yield high-quality sawlogs and veneer. The medium sites will yield box bolts and small, low-grade sawlog materials, but the main product on these sites will be pulpwood.

A certain percentage of the poor sites will yield some pulpwood, but a great portion of these areas is so-called "off-site" which does not yield merchantable products under present utilization standards. Thus, in the management of aspen, correct site determination is extremely important.

A site index table (11) as revised by S. R. Gevorkiantz is shown in table 2. This indicates that aspen varies widely in its rate of height growth on different sites, and serves as a guide for management.

Table 2.- Heights1/ of aspen on various sites, at ages 20 to 80 years

Age	Site				
	Excellent	Good	Medium	Poor	"Off-Site"
Years			Feet		
20	46	40	34	29	23
30	59	51	44	37	29
40	71	62	53	44	35
50	80	70	60	50	40
60	87	76	66	55	--
70	93	82	70	59	--
80	98	86	74	--	--

1/ Average for dominant trees in well-stocked, even-aged stands.

TOLERANCE

Although it is found as a temporary understory in certain forest stands, aspen is one of the most intolerant forest species in the Lake States. In order to attain its optimum development, the upper half of the crown must have full sunlight. Side shade, on the other hand, is beneficial in that it helps to develop straight, limb-free trees, and probably to a large extent prevents cankering. The latter seems to be the case especially when the understory is balsam fir or spruce.

Aspen growing in competition with overtopping trees becomes stunted, defective, and poorly formed; however, during its youth it responds readily to release.

GROWTH RATE

Aspen is known for its rapid growth. Under good conditions it will average 2 to 3 feet in height growth each year during the first 20 years of its life. On moderately productive sites it attains minimum pulpwood sizes in 25 years. Stands with less than full density may produce pulpwood even earlier.

Under the very best growing conditions, aspen will reach an age of 100 years, a height of 100 feet, and a diameter of 22 inches, but as a rule its maximum age on good sites is about 80 years. However, due to presence of decay and an increasing mortality during the later years, the rotation for management purposes should ordinarily not exceed 60 years. In pure stands on good sites, the best trees will at the latter age have reached a height of about 80 feet and a diameter of 15 inches. On average sites, the rotation must of necessity be less (about 50 - 55 years), at which time dominant trees reach a height of about 65 feet and a diameter of about 12 inches.

REPRODUCTIVE CAPACITY

Natural Seeding

Aspen is dioecious, i.e., male and female flowers are never produced by the same tree, but on separate trees.

Flowering usually takes place in May, and the seed ripens within 2 to 3 weeks after pollination. The seed germinates within a day or two when in contact with moist soil, but deteriorates rapidly if it falls on an unsuitable seedbed. Even under good storage conditions it will remain viable only a few weeks. Therefore, when planting stock is desired, the aspen seed must be sown immediately in well-pulverized seedbeds which must be kept moist and protected against excessive light and heat until the seedlings are well established (2). Aspen begins to bear seed when only 20 to 25 years old. This agrees with observations in the Northeast (21).

Despite the required combination of factors, such as good seedbed, good seed crop, and abundant moisture, many aspen stands have become established through natural seeding. Good seed years occur frequently, and some seed is produced nearly every year. The fine tufted seed is carried by the wind over great distances. Natural regeneration by seed often occurs when a fire exposes bare mineral soil during the spring of a good seed year.

Root Suckering

Aspen most commonly reproduces by root suckering following cutting. According to Kittredge (11), root suckers may spring up over a radius of 30 feet or more following the removal of an aspen tree. The root suckers are produced by the dormant buds (2) on the horizontal roots near the surface. These dormant buds, which are present in great numbers, are activated by the sudden strong light following removal of the mother stands. The suckers are usually produced during June. Under full sunlight they will attain a height of 3 to 4 feet by late fall. Both sexes of aspen produce root suckers.

ORIGIN OF ASPEN STANDS

PURE STANDS

Aspen is an extremely aggressive forest type. Johnson, Kittredge, and Schmitz (10) explain that aspen probably occurred in the original forest only in groups or as scattered individuals. As cutting and fires removed these older stands, numerous aspen suckers came up and formed groups. Subsequent fires killed these groups, and more aspen suckers came up from the established roots. Each new fire caused more suckering, and the aspen type spread rapidly. Shirley (16), however, besides recognizing the importance of suckers, also emphasizes the part played by seeding in the origin of aspen forests. No doubt a combination of seeding and subsequent spread by suckering following fire account for the presence of many even-aged stands of aspen.

MIXED STANDS

The best aspen is found on virgin forest soil, most frequently in mixture with hardwoods or white pine. Under such conditions it is not uncommon to find perfectly sound 80-year-old aspen 20 inches in diameter. In addition to aspen, a certain amount of reproduction of other and more tolerant species generally is present. Where such reproduction escaped damage from logging and fire, it became an understory or component of the more aggressive aspen suckers (10). The most common associate species of commercial importance are white pine, black spruce, white spruce, balsam fir, and hardwoods such as basswood, red maple, sugar maple, red oak, bur oak, white birch, and yellow birch. These mixtures indicate the best aspen sites. When white birch alone is the associate of aspen it generally signifies at least one past fire.

FACTORS AFFECTING MERCHANTABILITY

NATURAL ENEMIES

The aggressiveness and fast growth of aspen is to a great extent offset by losses from natural causes. The more important of these are discussed briefly.

Fires

Although fire has been the most powerful force in establishing present aspen stands, it should not be considered beneficial in their management. On the contrary, Stoeckeler (17-18) shows that the degree of soil deterioration caused by repeated fires is reflected in the quality of the subsequent stands. One fire, especially a light one, may not reduce the

site too seriously. Heavy or repeated fires, which often are followed by the establishment of pure aspen stands, rob the soils of organic matter and lower the quality of aspen even on the best sites.

Often a light ground fire in an aspen stand may not kill the trees or cause visible injury, but later the damage shows up in the form of decay.

The best quality aspen invariably is found on favorable soils in mixtures with other hardwoods which have escaped fire.

Wildlife

Aspen is a favored food for a number of wildlife species. It is the most important food for beaver. Utilization of aspen by beaver is confined to stream courses or other habitats favored by the animal. Deer feed freely on aspen. In areas of heavy deer concentration, they may cause considerable damage to young reproduction. Rabbits clip off young shoots and often girdle small saplings. Bark wounds caused by rabbits may start fungous infections.

Insects

An insect causing serious damage to aspen is the forest tent caterpillar (Malacosoma disstria). This has been studied extensively by Hodson (9). Contrary to its common name, this caterpillar does not spin a tent. The larvae feed on the leaves of aspen and birch. Ordinarily the damage is insignificant, but outbreaks during the early summer of successive years may cause the epidemic to spread over large areas. Fortunately there is but one brood a year. A single defoliation generally does not cause any damage beyond a reduction in the current season's growth, and new foliage is formed by midsummer. However, when defoliation is repeated the following year, it may result in considerable mortality, especially in the older age classes. Termination of outbreaks according to Hodson (9) may be caused by parasites and by weather conditions such as late spring frosts. The last large outbreak in Minnesota took place during the period 1935 to 1938. The area covered by this infestation was very large, and before the cycle ended very few untouched aspen stands remained in the northern part of the state. The mortality was especially heavy on the poor sites and in old stands where repeated defoliation had taken place. The larvae of this insect are very susceptible to DDT.

Another insect enemy of aspen is the popple borer (Saperda calcarata). It causes worm holes in standing trees and thus reduces the quality of the product. It also causes much damage by weakening the trees, subjecting them to breakage. The popple borer is a primary insect. It will attack vigorous trees, and is not confined to poor sites. There is a tendency for adult insects to attack trees adjacent to those where they were reared, according to information furnished by A. C. Hodson. These so-called "brood-trees" may be attacked repeatedly, causing stand openings. In partial cuttings of aspen, brood-trees should be cut in order to reduce future damage.

Aspen is also susceptible to various bark-injuring insects. Wounds caused by these pests often lead to canker infections. An important secondary insect is the bronze birch borer (Agrilus anxius) which tunnels under the bark of trees weakened by other causes.

Carpenter ants (Componotus herculeanus), which use the tunnels of the popple borer in the base of small trees, also cause considerable damage in young stands.

Diseases

Of the various diseases of aspen, one of the most common is the hypoxylon canker (Hypoxylon pruinatum). It causes very heavy losses, especially in younger aspen stands.

Hypoxylon canker is described by Lorenz and Christenson (12) as "probably one of the most important diseases throughout the range of the tree." Gruenhagen (8), in studies in Wisconsin, found 24 percent of all popple infected. Bier (5) reports that this canker is caused by a wound parasite, and that "bark punctures resulting from insect attack commonly serve as centers of infection." Gruenhagen indicates that spores are wind-borne. Bier points out that attacks are not confined to young trees, but rather to the young bark of all trees. Thrifty trees are as susceptible to the disease as suppressed trees. Gruenhagen found the canker most prevalent on poor sites and less infection on large trees. Baxter (3) apparently supports the latter view, and suggests maintenance of vigorous growth throughout the life of the stand as a control measure. Local observations in Minnesota seem to indicate that the canker is found most frequently on poor and medium sites, and on sites deteriorated by fires. The disease is much less common on good sites, especially when aspen is growing in hardwood mixtures. The latter is indication in itself that the site has not been deteriorated by fire. It has been observed also in Minnesota that aspen growing in mixture with balsam fir and spruce is relatively free from canker.

Another canker on aspen is Cytospora chrysosperma. It attacks young stems and twigs, which are thereby killed by girdling. There is some evidence that the Cytospora canker is a very weak parasite and not a primary invader of living trees.

Of the diseases which affect the utilization of aspen, wood rots are by far the most important. Rots are caused by the false tinder fungus (Fomes igniarius) and the butt rot fungus (Fomes applanatus). Of these, F. igniarius is the more serious, inasmuch as it may cause decay throughout the entire length of the tree. The spores of this fungus enter through wounds and bruises which expose the wood. Meinecke (13) estimates that one-third of the infections are caused by fire, one-third through bruises and cankers, and the rest through knots, roots, and minor wounds.

Three stages of rot are recognized; namely, (a) incipient, which causes slight discoloration of the wood; (b) intermediate, which causes brown discoloration without affecting seriously the hardness of the wood but makes it unsuitable for certain uses; and (c) the final stage, which causes punk and soft wood and is a serious defect. Ordinarily in the incipient stage there is no outward sign of disease. During the intermediate stage, small, round knobs appear on the trunk. When rot reaches its final stage, fruiting bodies, or so-called "conks" generally appear on the tree. Presence of conks indicates a high cull, and trees so affected generally are left standing by experienced cutters.

MERCHANTABILITY OF ASPEN AS AFFECTED BY NATURAL ENEMIES

Fire, wildlife, and insects, with the exception of wood borers, generally do not directly affect the merchantability of aspen. Indirectly, however, their effect may be great in that they provide an entrance for wood-destroying fungi.

Wood rot is the greatest single cause for cull in aspen. The intermediate stage of decay is recognized as a defect, but the wood is usable for various purposes such as box lumber, low-grade construction lumber, pulpwood, etc. The final stage of rot includes all stages of spongy wood, irrespective of color. This stage of decay is a serious defect and is culled by all industries using aspen lumber. Inasmuch as advanced rot generally affects only the core of a log, some decay is allowed in material sold for veneer and match stock, the amount depending upon the diameter of the bolt. A certain amount of final stage rot was permitted in pulpwood during the war, primarily in bolts of larger diameters.

On the basis of several logging studies conducted by the Lake States Forest Experiment Station, primarily within the Chippewa National Forest in Minnesota, it appears that site, stand age, and individual tree vigor as determined by visual appearance all affect the amount of decay in aspen stands. Satisfactory information on the interrelation of age and site is not yet available. However, Anderson (1) in his yield studies of aspen in Wisconsin found that the cull percent was highest on the poorer sites. Table 3, which is based on detailed scale records of several thousand trees on good sites and on estimated cull percent in unmanaged stands for lower sites is useful as a temporary guide for estimating the merchantable volumes in aspen stands in Minnesota. These trends in decay agree fairly well with those given by Schmitz and Jackson (15), but the individual values are somewhat at variance.

Table 3.- Usable sawlog volumes at various ages (percent) 1/

Site class	Age of stands								
	40	45	50	55	60	65	70	75	80
	Percent of gross volume merchantable								
Good 2/	90	87	85	82	76	68	57	47	25
Medium 3/	83	79	73	62	50	38	11	--	--
Poor 3/	75	54	33	14	--	--	--	--	--

1/ Volumes are by the Scribner rule for trees 7 inches d.b.h. and larger to a minimum top diameter of 6 inches inside bark and a minimum log length of 8 feet.

2/ Based on scale records in logging studies in northern Minnesota.

3/ Based on estimated cull percent in unmanaged stands.

That individual tree vigor within the aspen stands is closely related to cull as well as to growth was clearly demonstrated in a cutting study in a 50-year-old stand on the Pike Bay Experimental Forest in northern Minnesota. A 1-acre uncut plot, for which previous measurements were available, was chosen for the study. All the trees within the plot were remeasured prior to clear-cutting, and classified on the basis of their vigor, relation to surrounding trees, dominance, and crown density (7). Coincident with logging, the gross and net volumes were recorded for each tree. The results of this study are briefly summarized in table 4.

Table 4.- Cull percent and growth in relation to tree vigor

Tree vigor class	Average cull percent	Average last 5 years d.b.h. growth			
		Dominant	Co-dominant	Intermediate	Suppressed
		Inches			
1	5	0.75	----	----	----
2	17	0.55	0.36	----	----
3	20	0.50	0.29	----	----
4	35	0.46	0.30	----	----
5	50	----	0.25	0.21	0.10

The study shows clearly that the trees with the lowest vigor are the most defective and the slowest growing. These facts throw considerable light on the question of the most desirable cutting policy for aspen. Since the cull percent is much heavier in the smaller, weaker trees, the conclusion is that any partial cutting attempted should be "from below," at least in stands of this age class. A diameter-limit cutting which removes the larger trees will leave as growing stock the more defective portion of the stand.

YIELDS OF ASPEN IN UNMANAGED STANDS AS AFFECTED BY SITES

The yield of aspen is rather low compared with that of most other commercial forest species. Earlier estimates of volume yields were too high, chiefly because proper weight was not given to: (a) the exceptionally high natural mortality rate of the species; (b) the high cull percentage, especially in older stands; and (c) the natural slowdown in growth with age. Aspen needs much growing space. The high mortality rate, due to crowding and disease, is nature's method of providing this room. Anderson (1), as a result of yield studies by the Forest Survey in the Lake States, came to the conclusion that "the actual volumes in natural aspen stands in the Lake States fall so far behind normal yield tables that the usefullness of the latter is questionable." This is no doubt true for some of the earlier tables.

Table 5, however, which corrects some of the earlier errors, indicates yields that may reasonably be expected at various ages on good, medium, and poor sites in well-stocked unmanaged stands.

Table 5.- Yield of aspen by age and site classes.
Gross volumes per acre

Age Class	Site classes: Good	Medium	Poor	Good	Medium	Poor
	Standard cords1/			Board feet - Scribner2/		
20	8	..	..	.....	.....	.....
25	19	7	..	.....	.....	.....
30	29	16	5	1,300	300	.....
35	36	24	13	4,000	1,400	.....
40	42	30	17	7,000	3,000	1,100
45	46	32	18	8,500	5,000	2,400
50	47	33	16	9,000	6,000	3,000
55	46	30	13	9,100	6,000	2,900
60	43	26	10	9,000	5,800	2,500
65	37	20	6	8,400	5,200	1,800
70	29	14	4	7,400	4,500	1,400
75	21	9	..	6,000	3,200	700
80	12	4	..	4,200	1,500	.....

1/ Cords: Gross volume in standard cords of peeled wood in trees 4 inches d.b.h. and larger, to a minimum diameter of 3 inches inside bark.

2/ Board foot volumes are gross volumes by the Scribner rule of trees 7 inches in d.b.h. and larger, to a minimum diameter of 6 inches inside bark.

This table, prepared by S. R. Gevorkiantz for the use of the Forest Survey, checks very closely with observations from a number of logging studies and permanent sample plots on the Chippewa National Forest. It assumes a normal trend of mortality with advancing age, but does not take into consideration the sharply increased proportion of cull found in stands of advanced age. (See table 3.)

MANAGEMENT OF ASPEN

PAST CUTTING PRACTICES AND THEIR RESULTS

Because of various factors such as low stumpage prices and utilization practices, high reproductive capacity, etc., very few aspen stands in Minnesota have been given any sort of management in the past. Generally the merchantable volume was clear-cut at an advanced age, leaving undersized and cull trees. Attempts at management have consisted primarily of cutting to certain "diameter limits." In such cases, wind, sleet, and decay almost invariably have taken so heavy a toll in the residual stands that subsequent cuttings were impractical. Clear-cuttings and diameter-

limit cuttings, which were essentially merchantable clear-cuttings, have, however, in most cases resulted in satisfactory restocking of the areas. In many instances, past cuttings have resulted in desirable tree mixtures.

The poor utilization practices of the past have had two serious effects upon the condition of aspen stands now available for management; namely, (a) suppression of promising young growth by defective and undersized trees left; and (b) invasion by brush species which rob the soil of its nutrients and water, and slow down the growth of the new stand. As a result, many stands that have followed cutting of aspen, even on the best sites, will produce lower-grade materials than the original stand.

OBJECTIVES OF MANAGEMENT

Although the uses for aspen have been tremendously expanded during the past decade, we are currently consuming only one-fourth of the annual cubic volume growth of this species in the Lake States.

Considering the vast areas of aspen, and the amount of low-grade material which goes to waste every year, the primary purpose of management should be to improve the quality of the growing stock and wood products. Management for quality automatically will also result in greater quantity.

As seen from the previous chapters, aspen on the poorer sites is particularly susceptible to diseases. It grows slowly and produces less on these sites, and has relatively short life span. Management efforts, therefore, would be more wisely expended on the good sites.

EXTENSIVE MANAGEMENT

On large holdings, many of which at present lack even the crudest management, much can be gained by practicing extensive management.

Aspen stands on any large forest property consist of many different age classes as a result of past fires. The acreage in each class may vary a great deal and thus present an irregular pattern for management. The desirability of working toward an equal distribution of age classes is obvious. Once attained, an orderly marketing plan can be carried out and there will be less loss through mortality and defect.

The first step for the forest manager should be to classify the areas by site classes, segregating the sites into approximate age classes, and from this information decide upon a cutting policy. Following this initial step a more intensive management plan may be adopted during the next rotation.

The Chippewa National Forest provides a good illustration of how extensive management of aspen might be applied. In 1930, there were 4 more or less distinct age classes present; namely, ages 60, 40, 20, and 5. Cutting was progressing in the 60-year class which was already highly mature. The complete liquidation of this age class, however, was not

accomplished until 1940. In the meantime, the 40-year class had reached maturity and clear-cutting on the poorer sites was started. Removal of this low-site material has been possible due to large wartime demands, but complete disposal of this age class will not be accomplished until 1950 or 1955. By that time the next age class, which represents by far the greatest acreage, will be 40 to 45 years old and the forest would be faced with the disposal of tremendous quantities of material at one time. Foreseeing difficulties in having a large acreage mature at one time, the forest initiated a policy of clear-cutting of the medium sites in this age class (which is not yet fully mature) during the war, while the market would absorb smaller products. In the meantime, the cutting of the better sites in the older age class is being prolonged so as to maintain average quality products during the first few years of cutting the 40-year class. The liquidation of this age class should be completed by 1965 to 1970 at 55 to 60 years of age. In the meantime, the next age class will be 40 to 45 years old, and the reproduction resulting from clear-cutting of the original 60-year class will be just behind.

A balanced cutting program of this sort is hardly more difficult than indiscriminate clear-cutting. It will, however, pay generously in the form of more and better products, and pave the road to more intensive management.

INTENSIVE MANAGEMENT

At present it may seem impractical for owners of large holdings to apply intensive management to their aspen stands under the existing standards of utilization. However, owners of smaller tracts should be interested in forestry methods which will result in the greatest possible returns per acre. Whether or not the aspen market improves soon, the large owners will, in time, have to adopt better management practices if the quality of aspen is to be improved.

Thinnings

Aspen responds exceptionally well to thinning, especially during early life. Following fire or clear-cutting, aspen suckers often become established in such great numbers that the trees tend to stagnate before natural thinning becomes effective. Subsequently the stands suffer loss of vigor and become more susceptible to cankers and other diseases.

To what extent noncommercial thinnings will actually "pay" in the form of increased total volume yields is not certain. Considering the tremendous acreages and volumes of inferior aspen, perhaps we should not be too concerned about increased quantities. It is felt, however, that better-quality aspen could and should be grown on good sites.

Observations in young, thinned stands on the Pike Bay Experimental Forest indicate that they are relatively free from canker or other visible diseases 10 years after thinning. There also are indications that the rotation age, and thus the cull percent, may be reduced considerably

through thinning. In a normal rotation, larger, sounder, and more valuable materials will be the final result of early management. Thus, non-commercial thinnings may be justified for the sake of thriftiness alone.

Table 6 shows how quickly young aspen responds to thinning. At the time of thinning in 1936, the stems were very spindly and dominance was not clearly expressed. The stand is of sucker origin. The site index is 75 feet at 50 years.

The 5x5 foot spacing evidently was too light. The 10 x 11 foot thinning was too severe to obtain optimum 10-year increment. However, individual stems on this plot are growing rapidly and in time the stand will be fully stocked with large trees. The other three spacings appear promising. From the 10-year measurements, it was evident that the three closer spacings needed another thinning to maintain growth rate. However, in order to maintain the contrast between plots, a commercial cut of the same intensity was applied to all of the thinned plots. This cut, which removed four and one-half cords of pulpwood per acre, left the stands in excellent condition for future growth. At present, the original 8 x 9 foot spacing looks the most promising.

Table 6.-Results of thinning young aspen 1/

Spacing of trees left in thinning	After thinning - age 13					Ten years later - age 23				
	No. trees	Ave. d.b.h.	Basal area	Cubic feet	Merch. cords	No. trees	Ave. d.b.H.	Basal area	Cubic feet	Merch. cords
										3/
Check	3,633	1.6	53.9	610	...	1,333	3.0	66.7	1,257	7.37
5x5' 2/	1,717	1.8	30.3	372	...	1,383	3.2	77.8	1,479	10.50
6x6' 2/	1,217	1.8	21.4	258	...	1,075	3.6	77.9	1,559	12.81
7x7' 2/	975	1.9	18.9	242	...	933	3.9	78.1	1,659	15.87
8x9' 2/	545	2.2	14.3	190	...	512	4.9	66.9	1,320	17.49
10x11' 2/	396	2.1	9.6	128	...	359	4.8	44.9	887	11.38

1/ The plots were 0.6 acre each. The above figures are per acre.

2/ Approximate

3/ Merchantable pulpwood to 3-inch top inside bark.

Various other thinnings in young aspen stands show the same trend in development. In one stand, from which 5.8 cords of pulpwood were removed at age 30, measurements showed that 6.8 cords had grown back during the next 5 years. Inasmuch as the thinning had been made primarily from below, this rapid growth had been produced by the best individuals in the stand. During the same period, the uncut plot grew only 3.3 cords.

Another stand, which was thinned to a wide spacing at age 20 had at age 35 twice as much board-foot volume per acre as the unthinned plot, although some of the trees were inclined to be limby. This volume, too, was produced by a considerably smaller number of trees. It is evident in this experiment that the rotation in the thinned plots will be shortened by at least 10 years and that the trees then will be larger than in the uncut plot at normal rotation age.

Thinnings in Minnesota did not result in much sunscald as was reported to be the case in Canadian experiments (4).

Intermediate Cuttings

After a stand grows out of the cordwood class but before reaching the time for final harvest, there is a period of 15 or 20 years when it should be possible to make partial cuttings. These probably should be mainly aimed at improving the stand, but some valuable products such as box bolts and small sawlogs will result. In order to obtain information on what kind of a cut to make, a series of cutting plots on the Pike Bay Experimental Forest was established in 1935.

The plots were situated on a good site having a site index of 80 feet at 50 years. The 43-year-old stand was well stocked with 334 trees, and a basal area of 110 square feet per acre. Diameter-limit cuttings of 8, 9, and 10 inches were used. In addition, one plot was clear-cut and one left uncut. Remeasurements 6 years later revealed that the 10-inch diameter-limit cutting had produced considerably more total volume than any of the other cutting plots and slightly more than the check plot. In the 8-inch and 9-inch cuttings, the growing stock had been reduced too much while the check plot was too dense. Heavy cuttings, such as to an 8-inch or 9-inch diameter limit, have the further disadvantage that they open the stands sufficiently to encourage suckering, which is not desired before the final harvest, and stimulate brush invasion. When there is insufficient light, such as is the case following partial cuttings, the suckers do not develop properly and most of them are crushed later when the residual stand is cut. Indications are that suckers, which result from this final cut of the residual, somewhat weaker and more decadent trees may be less vigorous than those developed from the larger and healthier trees.

In the experiment just cited, a light diameter-limit cutting worked out fairly well, but it should be remembered that any cutting which leaves the smaller and less thrifty trees tends to increase cull percent of the residual stand. This was brought out previously in table 4. If, however,

for economic reasons, such as to eliminate marking costs, it is decided to use diameter-limit cuttings, it is essential first to determine the volume by diameter classes. This information serves as a guide in fixing the allowable cut as well as the diameter limit. In order to maintain the residual stand in a satisfactory growing condition, cuttings from above should not exceed 40 percent of the merchantable sawlog volume and about 15 percent of the merchantable trees.

For best silvicultural treatment of undisturbed stands on good sites, the intermediate cuttings should be made from "below." Small merchantable trees, which later will develop a high cull percent, should be removed. In addition, a few of the larger trees may be cut to improve distribution of the growing stock.

It may be impractical to mark all the trees to be removed. In this case it is necessary to mark only the larger trees which are to be cut because of poor form, defect, or poor distribution. In addition to marked trees, all stems below a certain diameter may then be cut for pulpwood or small logs without marking.

Rotation and Cutting Cycles

The greatest obstacle to management of aspen is heart rot, which increases rapidly with age.

From several cutting studies conducted on and in the vicinity of the Chippewa National Forest, it was found that even on good site the maximum gross volume in unmanaged stands was produced between ages 55 and 60. The greatest net volume, however, was produced between ages 50 and 55. Table 3 shows the increasing cull percent with age and table 5 indicates a reduction in gross volume.

In some cases it may be desirable to sacrifice volume in order to obtain larger diameters, such as for veneer. However, when it is considered that nearly half the volume may be lost during the additional period it takes to grow the larger products, these must bring a stumpage price of approximately 3 times the normal rate in order to compensate for the loss of volume and time.

A rotation of about 55 or 60 years, therefore, seems best for unmanaged aspen on good sites in Minnesota. Early thinnings in order to favor best-quality trees, however, will undoubtedly produce desired sizes at an earlier age. Under the most intensive management practices, commercial thinnings should be started at age 25 to 30. When the stand is mature, it should have had 3 to 4 such thinnings or improvement cuttings, which will then leave a fully stocked stand of 200 to 250 of the straightest, soundest, and most vigorous trees for the final cut. The final harvest should be a complete clear-cutting.

REGENERATION OF ASPEN

Regeneration of aspen by natural seeding, as previously pointed out, takes place only under certain conditions, such as following severe fires which remove competition and expose mineral soil. In actual forest management, however, no certain means have as yet been found to obtain aspen stands by natural seeding. Although planting is used in other countries (2), this method of regeneration is still too expensive here, considering the ease with which fully stocked stands can be obtained through root-suckering.

Following clear-cutting, aspen suckers generally appear in sufficient numbers to form fully stocked stands. The first prerequisite for satisfactory aspen suckering is an abundance of sunlight. It is imperative, therefore, that a thorough job be done in removing the old stand. Unmanaged stands always contain a number of cull trees which cutters are inclined to leave. Leaving such trees standing not only decreases the number of root-suckers, but the shade of these trees seriously hampers the growth and development of the reproduction and causes an even higher degree of defect in the next rotation. In any clear-cutting job, therefore, all aspen should be cut down whether merchantable or not.

Aspen Root-suckers as Future Stands

There is some question as to whether second-growth stands resulting from suckers will make as good trees as the mother stand. The alarmingly high mortality in young sucker stands and the wood discoloration found in a great number of stems raises a question as to whether rot in the mother tree is transferred through the roots to the suckers. Possibly rot is transferred from diseased roots to suckers but not from a decaying stump. That deterioration of the stump allows rot to travel through the roots to the suckers is very questionable inasmuch as the rots which cause deterioration of dead wood do not attack living tissues. Furthermore, as the suckers become established, they form their own root system and no longer depend on the mother root for their food. Schmitz and Jackson (15) found no evidence to prove that suckers are infected by the parent stump through the roots.

In most merchantable stands, a certain number of trees are vigorous and free of rot. It is expected that these, at least, will produce rot-free suckers.

In an attempt to find out the incidence of decay in suckers, two stands of sucker origin, 10 and 23 years old, were examined to determine presence of stem discoloration which may be an indication of rot. A strip was cut at random through each of the stands, and each tree was classified as to dominance and degree of discoloration. In the 10-year-old stand it was found that of a total of 4,800 stems per acre, the wood of 2,210 trees was unaffected by any stain whatever. Of this number, 875 were dominant trees. In the 23-year-old stand there were 3,100 stems per acre. Of these, 1,015 were free of discoloration and 385 were in the dominant class.

To what extent discoloration is a true indication of rot is not known. It is clear, however, that trees without discoloration are free from rot. There are more than enough of these to assure a fully stocked stand.

Suckering as Affected by Season of Cutting

The general opinion that clear-cutting of aspen results in abundant regeneration through suckering is based on the fact that most aspen logging has been carried on during the fall and winter months. Good reproduction generally occurs following such operations, especially when the stands are not overmature and when a good job of clear-cutting has been done.

The heavy wartime demands for lumber and the increased production of aspen pulpwood during the past decade has, however, resulted in a considerable trend toward summer logging. Local observations and examinations in northern Minnesota show that aspen regeneration is to a large extent unsatisfactory on areas logged in summer, even where properly clear-cut. In many cases, heavy brush cover is taking over the site. These observations on the failure of summer-cut aspen to sprout vigorously agree with results of an experiment in Wisconsin reported by Stoeckeler (19).

There may be several reasons for these failures. It is possible that the aspen roots during the active growing season are depleted of their stored food and thus lack some of their ability to produce vigorous sprouts. A more tangible reason is that suckers produced the same summer become established so late in the season that most of them are winter killed. The natural season for suckering to start after a winter logging job is about mid June. After summer logging, however, most suckering takes place the following year. In the meantime, the brush species which were present at the time of logging have had time to recuperate and constitute serious competition for the nearly established aspen suckers.

As a result of these observations, it is recommended that the final cut of aspen on good sites be made between October and April, so far as practicable. Summer cutting should be concentrated on such sites where reproduction of aspen is not desired.

Increasing Suckering

Where aspen for various reasons fails to reproduce following the final cut, the forest manager must help nature. Since full sunlight is needed, the final cut should remove all of the overstory, including cull aspen and other species of inferior quality. If reproduction fails to become established due to other causes, such as summer logging or dense brush cover, more drastic measures must be taken.

The present stands became established as a result of fires. Fire, however, as a tool in human hands, thus far has not been used to obtain aspen reproduction. Furthermore, Stoeckeler (20) shows that past fires have definitely deteriorated the sites. In a search for a practical and

inexpensive solution to this problem, a cutover area on the Pike Bay Experimental Forest was cross-disked with an Athens type disk plow. The area chosen had been summer-logged three years previously. It was extremely brushy and had a scattered overstory of cull trees left. A survey prior to disking showed 61 percent stocking with 750 aspen sucker clumps per acre. When the area was re-examined in the fall following disking, it had a stocking of 91 percent of new aspen suckers, or 2,400 clumps per acre. The stocking inside a 50-foot radius of standing cull trees was 100 percent, with 5,300 sprout clumps per acre resulting from disking. In this case there evidently were sufficient living aspen roots (probably from standing cull trees and existing reproduction) in the ground to assure a well-stocked stand of aspen suckers. No doubt, elimination of some of the competing brush also helped. The root injury caused by disking probably stimulated suckering.

Disking two to three years following logging has the advantage that the slash has decomposed to an extent where it does not seriously hamper machine operation. Unquestionably, the aspen reproduction will be denser and more vigorous when disking is done earlier, and less time will be lost in growing the new crop.

RECOMMENDATIONS

GOOD SITES

During the early life of a pure aspen stand it often is difficult, even for the professional forester, to determine whether the stand is adaptable for quality production.

1. Good sites especially are well-adapted to intensive management.

2. Clay loam or silt loam soils, which originally supported good-quality hardwoods or white pine, make good aspen sites if they have not been too severely burned. Some former spruce-fir lands with good drainage are also good aspen sites.

3. Young aspen stands on good sites generally are characterized by straight, thrifty appearing, canker-free stems with greenish bark.

It is too early to predict how much effect thinnings and intermediate cuttings will have in increasing the quality and quantity of the future volume of aspen stands. The foregoing observations and demonstrations seem to indicate that such cultural treatments are profitable where markets exist for small products.

Where intensive practice is feasible, the following system of management is recommended for aspen on good sites:

1. Start management early. Keep the stand thrifty. Make a noncommercial thinning before age 20 to improve spacing. A spacing of about 8x8

feet appears desirable. Remove all poorly formed and diseased trees. Reduction of cull, better growth, and improved quality of the crop trees are the principal benefits of this initial cutting.

2. As the stand closes, pulpwood cuttings may be made at 5 to 10 year intervals. From 4 to 6 cords of bolts per acre should be removed each time. These harvests should remove the smallest and poorest trees, favoring 250 to 300 of the best stems per acre for crop trees.

3. By age 40 to 45, all inferior trees should have been removed and the number of crop trees reduced to 200 to 250 per acre which will be available for the final cut.

4. The stand should be clear-cut at age 50 to 55. On the very best sites, however, the final harvest may be delayed until age 60 without serious loss due to cull.

The best aspen is produced in mixed stands on good sites. Its quality and growth on these sites often is superior to its associates. When such proves to be the case, aspen should be encouraged in partial cuttings. This can be facilitated greatly by eliminating low-value or poor-quality hardwood species around stumps of freshly cut aspen. Full sunlight is thus provided for the aspen suckers.

Where balsam fir, spruce, or white pine occupies the understory, the mature aspen should be removed gradually. Otherwise these conifers, which grow well under a partial shade, may suffer shock due to sunscald or similar types of injury.

It also should be borne in mind that aspen ordinarily will remain sound longer and attain a more advanced age in mixed stands than in pure stands.

When mature aspen occurs in mixture with pole or small sawlog-size oaks, these should be left when the aspen is clear-cut. In most cases they will continue to grow until the end of the next aspen rotation. Where paper birch is mixed with aspen, it should be cut with the aspen at the end of the rotation. Sudden exposure of birch causes high mortality and induces attacks by the bronze birch borer, with the result that within a few years most or all of the birch is killed.

MEDIUM SITES

These sites constitute a wider variety of soils than good sites. Most common are those which formerly supported poorer grade white pine or hardwoods and mixtures of white and red pine. They also include former good sites which have been severely or repeatedly burned.

Medium sites generally are characterized by somewhat poorer forms of the young aspen stems. The bark of the young stems generally is whiter on medium sites and some canker may be found early in life.

Management of aspen on medium sites should be primarily for pulpwood and box bolts. The merchantable life span on such sites is only 10 to 15 years

(between ages 30 to 45). Aspen on such sites should be clear-cut and reproduced during this period. It is better to start cutting a little too early in such stands than too late. The following steps can be recommended:

1. A noncommercial thinning to improve the growing space before age 20 will greatly improve the quality. A spacing of about 7 x 7 feet seems feasible. Wider spacings will have a tendency to spread canker through sunscald.

2. Make a commercial pulpwood cut 7 to 10 years following the first thinning, favoring about 300 of the best trees per acre. Follow this with a second pulpwood cut 7 to 10 years later, leaving 200 to 250 stems per acre of the largest, thriftiest, canker-free trees.

3. Clear-cut the stand at age 40 to 45 for box bolts and pulpwood. Watch the stand closely, and clear-cut sooner if canker becomes prevalent. If through judicious cutting the stand is still growing well and the trees are sound and canker-free, the rotation age may be extended to 50 years in order to obtain larger sizes.

It is assumed that through soil build-up and fire protection, some of the medium sites will produce better aspen during the next rotation.

The medium sites generally are better suited for other species than aspen. In partial cuttings, therefore, such species as white pine, red pine, spruce, and oak should be favored so as to induce stronger mixtures and gradual conversion to better species.

POOR SITES

These include all sites which formerly supported pure red pine or red and white pine mixtures severely burned. Poor sites generally are characterized by deformed aspen stems, a whiteish gray bark, and a high mortality rate, primarily due to canker.

Most aspen on such sites does not even reach pulpwood size under the present utilization standards. In cases where it does, the merchantable life span is very short, generally only 5 to 10 years. Clear-cutting is recommended as soon as the stand can be commercially cut. Schantz-Hansen (14) states that on the Cloquet Forest aspen deteriorates rapidly from age 25, and that it is wise, therefore, to harvest the stands while they have a commercial value. He shows that growing and harvesting of aspen on poor sites can be profitable in the vicinity of a wood-conversion plant which uses small-size pulpwood. For most poor aspen sites, however, Shirley (16) suggests converting to conifers by planting.

SUMMARY

1. Aspen management has received very little attention in the past. With the dwindling supply of other species and increasing demands for wood products, more attention is being focused on aspen and its management possibilities.

2. Aspen is the most extensive forest type in the Lake States where it constitutes approximately 40 percent of the commercial forest area. Its commercial volume was greater in 1946 than 10 years previously, due partly to growth and partly to closer utilization standards. Despite its wide variety of uses and increased utilization, less than half of the annual growth is consumed.

3. Although aspen is found on a wide variety of soils, it is very sensitive in regard to site requirement. On sites well adapted to aspen, it develops into a good tree; on sites poorly adapted, it is scrubby and decays at an early age. It is estimated by the Forest Survey that only 15 percent of the aspen acreage is on good sites; medium sites constitute 54 percent; and poor sites 31 percent.

4. Aspen grows rapidly, but this is to a great extent offset by its high rate of mortality. Former estimates of volume yield were too high. Aspen has many enemies. The most serious are cankers and woodrots. The latter are the primary cause for cull, which increases with age.

5. Past cutting practices included clear-cutting and diameter-limit cuttings. Both methods have been poorly applied and resulted in inferior second-growth stands. Diameter cuttings may have a place in management if they are properly applied so as to leave sufficient growing stock.

6. Aspen on good sites lends itself to intensive management. It responds exceptionally well to thinnings and early improvement cuts. Experiments show that aspen should be cut from below in order to develop high quality material, and prevent mortality and cull.

7. Considering that less than half of the annual growth of aspen is consumed at present, efforts should be concentrated on the development of quality rather than quantity. The best aspen grows on the good sites. Intensive management, therefore, should be confined to such sites at least for the present.

8. Aspen stands reproduce after cutting primarily through root suckers, which must have full sunlight in order to develop properly. Unmanaged aspen stands nearly always contain a large number of cull trees, which are generally left by the cutters. The shade of such trees seriously hampers reproduction establishment and growth, and it is essential that they be felled at the time of clear-cutting.

9. Regeneration of aspen by suckering is less certain to succeed following summer logging than winter logging. In Minnesota this is primarily due to brush competition.

10. Aspen suckering can be stimulated by disking, especially if cull trees have been left standing. Disking reduces brush competition and permits light and heat to reach the soil surface. Once well established, aspen suckers will quickly outgrow the brush.

LITERATURE CITED

(1) Anderson, Robert T.
1936. Yields of Aspen in the Lake States. Lake States For. Exp. Sta. For. Res. Digest, May 1936.

(2) Barth, Agnar
1943. Aspen, Dens Kultur og Behandling for Kvalitets Produksjon. Publication No. 1., F. H. Frolich Fund for Advancement of Aspen Management, Translated from Norwegian by P. Zehngraff.

(3) Baxter, D. V.
1943. Pathology in Forest Practice. 618 pp.

(4) Bickerstaff, A.
1946. The Effect of Thinning upon the Growth and Yield of Aspen Stands. Dominion Forest Service Silvicultural Research Note No. 80. 25 pp. (processed)

(5) Bier, T. E.
1940. Studies in Forest Pathology. III Hypoxylon Canker on Aspen. Dom. Canada, Dept. Agr. Pub. 691, Tech. Bull. 27.

(6) Cunningham, R. N.
1946. Revised Forest Statistics for the Lake States, 1945. Lake States Forest Exp. Sta. Station Paper No. 1. 27 pp. (processed)

(7) Gevorkiantz, S. R., Rudolf, P. O., and Zehngraff, P. J. 1943. A Tree Classification for Aspen, Jack Pine, and Second-growth Red Pine. Jour. For. Vol. 41, 4, April 1943.

(8) Gruenhagen, R. H.
1945. Hypoxylon Pruinatum and its Pathogenesis on Poplar. Phytopathology 35: 72-89.

(9) Hodson, A. C.
1941. An Ecological Study of the Forest Tent Caterpillar in northern Minnesota. Univ. of Minn. Agr. Exp. Sta. Tech. Bull. 148, 55 pp.

(10) Johnson, R. P. H., Kittredge, J., and Schmitz, H. 1930. Univ. of Minn. Agr. Exp. Sta. Tech. Bull. 70.

(11) Kittredge, Joseph, and Gevorkiantz, S. R. 1929. Univ. of Minn. Agr. Exp. Sta. Tech. Bull. 60.

(12) Lorenz, R. C., and Christensen, C. M. 1937. A Survey of Forest Tree Diseases and their Relation to Stand Improvement in the Lake States. (Processed)

(13) Meinecke, E. P.
1929. Quaking Aspen. A study in Applied Forest Pathology. USDA Tech. Bull. 155.

(14) Schantz-Hansen, T.
1945. Harvesting Young Aspen on the Cloquet Forest. Jour. For. Vol. 43, 7. July 1945.

(15) Schmitz, Henry and Jackson, Lyle W. R.
1927. Heartrot of Aspen. Univ. of Minn. Tech. Bull. 50. 43 pp.

(16) Shirley, H. L.
1941. Restoring Conifers to Aspen Lands. U. S. Tech. Bull. 763.

(17) Stoeckeler, J. H.
1940. Memorandum on Aspen Site Study. Lake States Forest Exp. Sta., January 1940. (Unpublished report)

(18) Stoeckeler, J. H.
1945. Nutrients in Duff and Humus Layers Increase Growth in Forest Plantations. Lake States For. Exp. Sta. Tech. Note 226.

(19) Stoeckeler, J. H.
1947. When is Plantation Release Most Effective? Jour. of For. 45: 265-271.

(20) Stoeckeler, J. H.
1947. The Growth of Quaking Aspen as Affected by Soil Properties and Fire. (Unpublished manuscript)

(21) Weigle, W. G., and Frothingham, E. H.
1911. The Aspens: Their Growth and Management. USDA Forest Service Bull. 93, May 1911.

LAKE STATES ASPEN REPORT NO. 22

ENEMIES OF ASPEN

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JANUARY, 1951

——PROCESSED BY——
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (*Populus tremuloides*) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up to date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

Report Number	Subject
1	Aspen Properties and Uses
2	Aspen Availability and Supply
3	Logging Methods and Peeling of Aspen
4	Milling of Aspen into Lumber
5	Seasoning of Aspen
6	Aspen Lumber Grades and Characteristics
7	Mechanical Properties of Aspen
8	Machining and Related Properties of Aspen
9	Aspen Lumber for Building Purposes
10	Aspen for Containers
11	Aspen for Core Stock
12	Small Dimension and Other Industrial Uses of Aspen
13	Aspen for Veneer
14	Aspen for Pulp and Paper
15	Aspen for Cabin Logs
16	Aspen for Excelsior
17	Aspen Defiberization and Refining of Product
18	Chemical Utilization of Aspen
19	Preservative Treatment of Aspen
20	Marketing of Aspen
21	Possibilities of Managing Aspen

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LAKE STATES ASPEN REPORT NO. 22

E N E M I E S O F A S P E N

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REPORT NO. 22

ENEMIES OF ASPEN

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So long as aspen was considered primarily a weed species, there was little concern over the enemies which might injure or destroy it. Sometimes these enemies were actually considered blessings in disguise. Now, however, that aspen not only is the most abundant but also one of the most widely utilized tree species in the Lake States, there is increasing interest in anything that may affect its future supply. For that reason this brief summary of information on the enemies of aspen has been assembled.

The diseases of aspen, notably cankers and woodrots, have caused great concern. However, there are also many other factors which kill or damage aspen trees in the Lake States. Among them are more than a score of insects, several species of mammals and birds, storms and other weather factors, and fires. Often there is an interaction of injurious agencies. For example, trees may be injured initially by storms, animals, or fires, and subsequently insects or disease causing organisms may enter such trees and further weaken or kill them.

DISEASES OF ASPEN[2/]

The diseases of aspen and their effects on the growth and productivity of the trees, management of stands, and utilization have been studied but little in the Lake States. It is apparent, however, that leaf diseases probably are of little importance, that Hypoxylon canker is an important killer of trees in many areas, and that decay caused by Fomes igniarius results in serious reduction of wood volume in older trees. A number of studies of the Hypoxylon canker problem are in progress and some results should be available in the near future.[3/]

1/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota, University Farm, St. Paul 1, Minnesota

2/ This section was prepared by Clyde M. Christensen, Professor of Plant Pathology, University of Minnesota, and Ralph L. Anderson, Research Assistant, University of Minnesota, and Agent, Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A.

3/ Studies are being conducted by the U.S.D.A. Division of Forest Pathology, University of Minnesota, the Lake States Forest Experiment Station, University of Wisconsin, University of Michigan, Michigan State College, and several cooperating pulpwood companies.

U.S.D.A. - S.C.S. Milwaukee, Wis., 1951

Leaf Diseases

Leaf diseases do not seem to be of much importance in the management of aspen, but they should be recognized for what they are. Usually they appear in epidemic form only sporadically, and they seldom cause sufficient defoliation to measurably affect the health, vigor, or rate of growth of the trees. Those commonly encountered are described briefly below.

Napicladium tremulae causes a dieback of young tender shoots and leaves of aspen from Maine to Minnesota. Infected terminal twigs usually wilt in early July, and soon turn black. This disease is of wide geographic distribution in aspen suckers, but is not known to cause loss of any significance throughout the range of aspen. Young suckers coming up in very dense stands immediately after clear cutting do not appear to be damaged by this disease even when the growing season is excessively moist.

Sclerotinia whetzelii causes Ink Spot, so named from the black circular spots up to 1/4 or 1/3 inch in diameter that develop on infected leaves during the summer. The spots are raised slightly above the surface of the leaves. Ink Spot is widely distributed and relatively common on quaking aspen, but rare on bigtooth aspen. In eastern Canada the disease sometimes reduces the growth, or even kills trees less than 8 feet tall, but apparently has no serious effect on older, taller trees. In the Lake States, occasional local infections have been found heavy enough to cause noticeable browning of the foliage of relatively large and mature trees, but such infections have no more than a very slight and temporary effect on the vigor of the trees.

Septoria musiva infects the leaves of balsam poplar and causes irregular brown spots which are so common that they are almost an identifying character of balsam poplar. The browning of the leaves caused by this fungus usually does not become extensive until late in August when the trees are almost going into dormancy. It is unlikely that heavy infections this late in the season have an effect any more serious than inducing defoliation slightly in advance of normal. On a number of hybrids and introduced species of poplar, the same fungus causes cankers which often kill the trees, but on the species native to the Lake States it appears to be of little importance.

Several species of Melamosora cause rusts on the leaves of poplars. In the Lake States, heavy infections have been found on cottonwoods, but the defoliations caused were usually so late in the season as to have little noticeable effect on the health or vigor of the trees. Heavy infections of rust on the leaves of forest grown aspen have not been reported.

Cankers

Canker caused by Hypoxylon pruinatum is unquestionably the most serious fungus disease of aspen in the Lake States. Trembling aspen is highly susceptible to Hypoxylon canker, bigtooth aspen is injured occasionally, and balsam poplar rarely is attacked.

The fungus invades the bark of the branches or trunk only through wounds. Experimental evidence indicates that "clean" cuts such as those made with an axe or a knife do not become readily infected, but if the bark is bruised severely, as by striking it with a hammer, 50 to 60 percent of the bruises may be infected. Artificial inoculations of trees indicate that wounds can be invaded by the fungus only when they are very new, before the bark tissues form cork layers to wall off the wound. It is possible that wounds made by some insects permit the fungus to invade the tree.

Within a few weeks after the fungus invades the bark, yellowish, sunken areas appear. These extend relatively rapidly up and down the trunk, but progress more slowly around the trunk. The fungus digests much of the inner tissue of the bark, forming a crumbly black residue laminated with lighter colored layers. If the outer bark is removed from the advancing edge of a canker, a sharp division is seen between the green inner bark of the healthy, noninvaded portion and the black inner bark of the diseased parts. Usually no callus tissue is formed at the border of the canker, probably because the fungus progresses too rapidly to permit this.

The fungus kills the tree by girdling the stem. Small trees may be killed in two or three years, those up to 4 inches in diameter in 5 to 7 years, and larger trees in 10 to 15 years. Sometimes the infected trees die before they are completely girdled. The fungus also decays the wood of the stem relatively rapidly, and the trees usually break off at about the middle of the canker, either shortly before or shortly after death.

Data gathered from sample plots by several different investigators, in different parts of the principal commercial range of aspen in the eastern United States and Canada, indicate that about 20 percent of the trees were either infected at the time of investigation or had been killed by Hypoxylon canker previously. Maximum infection in these studies was about 60 percent of the trees. Infections on branches usually kill only the branches and do not enter the trunk; those on the trunk within the crown may kill only that portion above the canker; but those below the crown are almost invariably fatal to the tree. Heavy infections frequently reduce stand density far below that desired. Trees that could otherwise be harvested in thinnings often are eliminated by the canker. In the Lake States, many young stands are so heavily infected as to be without present or future value. The opening up of aspen stands by Hypoxylon canker may aid succession to more valuable species on some sites, but this is a relatively minor benefit compared with the over-all damage caused to aspen by the disease.

Most investigators of Hypoxylon canker agree that young trees, or the younger portions of old trees, are more susceptible to infection than are the trunks of mature trees. This is borne out by experimental inoculations made by one of the writers -- a high percentage of the trees 3 to 4 inches in diameter became infected, but almost none of the 8- to 10-inch trees did.

Some evidence indicates that the incidence of infection is higher on the poorer than on the better sites. Factors other than site index may have been involved, and further data on this question will be required before a really conclusive answer can be given as to the relation between site index and damage caused by Hypoxylon.

More conclusive data are needed as to the relation of diameter of trees to infection by Hypoxylon, although the trunk does appear to become progressively less susceptible to invasion as it increases in diameter and the bark becomes thicker. The relation of tree vigor to infection also is not yet clear, although observations made by one of the writers in 1949 tend to support earlier Canadian studies which indicated that the more vigorous trees are just as susceptible to infection as the less vigorous ones. Current research indicates that infection in well stocked stands is less than in poorly stocked stands. Understocking, therefore, may favor increased incidence of the disease.

No specific control measures have yet been formulated, but common sense suggests that, in thinning operations, all trees infected by Hypoxylon be cut. If left standing they not only will be killed by the fungus in a few years but will also furnish a source of inoculum to infect the remaining trees.

Nectria parasitica causes occasional cankers on aspen. Usually these are oval, with prominent successive ridges of callus tissue or wood from which the bark drops off. Sometimes, especially on slow growing trees on poor sites, Nectria cankers may extend for several feet along the trunk, and the bark will remain on, so that the cankers are evident only by a sunken area on the trunk. Usually the fungus advances very slowly through the bark, and an infection of 15 or 20 years' standing may be only 8 or 10 inches wide and involve only 1/4 to 1/3 the circumference of the trunk. Nectria seldom kills trees, and it does not decay the wood. It even seems to protect the wood from invasion by wood rotting fungi that normally would enter such exposed portions of the trunk.

Since Nectria cankers seldom are common on aspen and when they do occur rarely kill the tree or expose the wood to invasion by decay fungi, they do not seem at present to be of much practical importance.

Cytospora chrysosperma, according to good evidence, is a normal inhabitant of the bark of aspen, and invades the living portion of the bark only when the tree is dying of other causes. One of the writers inoculated numerous aspen trees with cultures of Cytospora from several different sources, and not a single canker resulted. However, when the trees died

several years later as a result of constriction from metal bands fastened around their trunks, Cytospora fruited throughout most of the bark of the trunk shortly after the inner bark below the constricting bands was completely dead. Cytospora canker may be of some significance on introduced varieties or on some hybrids, but there is no evidence to indicate that it is more than a saprophyte in the bark of forest aspen.

Roughbark

Macrophoma tumafaciens infects the outer bark and causes roughbark of aspen, a condition in which the normally smooth, white bark of the trunk becomes roughened and dark, usually in bands that extend part or all of the way around the stem. Other fungi and also lichens may possibly cause similar symptoms. Roughbark as such has no measurable effect on the health or vigor of the trees, but some observational evidence indicates that roughbark is likely to be more prevalent and prominent on trees growing on poor sites. Thus the presence of roughbark may be an added, but not infallible, criterion of site quality.

Decay

Fomes igniarius is the principal cause of heartrot in aspen throughout the entire range of the tree. It invades the tree chiefly through branch stubs, progresses upward and downward in the inner wood of the trunk at the rate of a few inches to a foot or more per year, decays and consumes the wood, and eventually forms fruiting bodies or conks at the branch stubs. The conks are hoof-shaped, black on top, brown on the bottom, and are well known to most foresters who deal with aspen. When first formed, the conks are little more than a brown crust on the under side of a branch stub, but they increase slowly in size from year to year. They are difficult to see until they are at least 5 to 10 years old. It has been stated that the presence of a conk of this fungus on the trunk of aspen indicates decay from 4 to 6 feet above and below the place where it occurs. While such a rule-of-thumb might apply to a given locality, it probably could not be considered a reliable general rule. Obviously a tree with a single conk two years old would have less extensive decay than one with a conk 20 or 30 years old. Factors such as site index, amount of suppression, rate of growth of the tree and others would make it difficult to establish any general rule for accurately estimating cull from conks or other outward symptoms.

Since Fomes igniarius enters chiefly through branch stubs, and branch stubs normally become more numerous as aspen trees grow older and the lower branches become shaded out, decay will increase with increasing age of the trees. Studies made in Minnesota some years ago indicated that as aspen increased in age beyond 50 years, the loss of wood volume from decay began to exceed the annual increment of sound wood, and that this loss from decay became progressively greater as the trees grew older. While these general conclusions are of considerable value in telling us how

Fomes igniarius operates, they are subject to considerable modification in the handling of individual stands of aspen. In some areas, there is relatively little decay in aspen even when it has exceeded an age of 50 years; in others, decay causes heavy losses before the trees become 50 years old.

What the wood is to be used for may have an important bearing on the loss caused by Fomes igniarius rot. Where the trees are cut for lumber or dimension stock, decay is obviously important, especially since it reduces the amount of sound material that could otherwise be obtained from the central portion of the trunk. Recent unpublished studies made by one of the firms using aspen in the manufacture of insulation board indicate that even extensive decay results in relatively little loss in volume of final product obtained from the tree. This suggests that for certain uses trees decayed by Fomes igniarius need not be discriminated against. Obviously, rather intensive studies are needed to determine the relation of this rot to aspen management in specific areas, and for specific purposes.

Fomes applanatus rots the roots and butts of occasional aspen trees, but is not known or suspected to be sufficiently prevalent to cause much loss.

When aspen logs are cut and piled, they are soon invaded by a great variety of wood-rotting fungi that gradually decay them. There are several dozen species of wood-rotting fungi known to grow vigorously in moist aspen wood. If the wood is piledwhere it does not dry out readily, these fungi are able to cause some reduction in volume, and in quality for certain uses, during a single summer, and considerable loss during the course of two summers. All or nearly all of these fungi cause white rots. Presumably a certain amount of this decay does not greatly reduce the volume or quality of the wood for certain purposes, but eventually, of course, the major portion of the wood is consumed. No detailed studies of the practical significance of these rots have been reported, but such studies are needed to give added information on the utilization of aspen.

ASPEN INSECTS IN THE LAKE STATES[4/]

Among the various insects known to attack aspen, the leaf-feeding species usually cause the most conspicuous and important damage. They are represented by insects which produce all five major types of leaf injury; namely, free feeders, skeletonizers, leaf rollers, leaf miners, and gall makers. Of these, the free feeders such as the forest tent caterpillar have been the most destructive. There are also a number of wood-boring insects found in aspen, of which only the poplar borer is of particular economic significance. Of less importance are several species of scale insects and aphids which commonly are present in aspen stands.

4/ This section was prepared by A. C. Hodson, Professor, Entomology and Economic Zoology, University of Minnesota; published as University of Minnesota Agricultural Experiment Station Miscellaneous Journal Series No. 736.

Leaf Feeders

The forest tent caterpillar, Malacosoma disstria, is unquestionably one of the most important insect pests of aspen. Not only does it cause mortality or a great reduction in radial growth in completely defoliated stands, but also it is considered a serious nuisance by residents and visiting tourists in areas where outbreaks occur. In fact, the indirect economic losses and annoyance suffered in resort areas often may be more important than direct damage to the forest. On the other hand, the forest tent caterpillar has been considered a beneficial insect because of the release given desirable conifers when poor-site aspen is killed by repeated defoliation. Although there is actually little or no observational evidence to support this opinion, it does seem to be a reasonable assumption which should be investigated.

On the average the eggs of the forest tent caterpillar hatch during the first two weeks in May in the latitude of northern Minnesota. At first the feeding of the small larvae is scarcely noticeable but by early June, after the fourth molt takes place, defoliation proceeds at a very rapid pace. In fact, the last instar larvae consume about 80 percent of the foliage eaten during the entire feeding period. This explains why many people have thought that there was no need for spraying in May only to have the older larvae appear as if from nowhere later in the season. About the middle of June the larvae spin cocoons in the leaves of the host trees and in woody shrubs and ground vegetation. Pupation takes place in the cocoons and is followed by moth emergence, usually during the first three weeks of July. The eggs are deposited in masses that encircle the twigs of the host trees. They develop until ready to hatch and then become dormant until spring.

Records show that there have been forest tent caterpillar outbreaks in the Lake States at approximately 10-year intervals. They have persisted for a few years and then the insects have subsided to a very low population level, even to the point of complete local disappearance. In most cases, complete defoliation has been observed for no more than three successive years in any one locality. However, a major outbreak may continue for five or more years over a large area, dying out at the initial points while continuing to build up over an increasingly large acreage. The records available also suggest that the outbreak which terminated in Minnesota in 1938 was of longer duration and much more extensive than those recorded in former years. This change is associated with the tremendous increase in the acreage occupied by aspen over the past 50 years, and suggests what we may expect in the future.

The current outbreak, which was noticed first in Minnesota in 1948 at Basswood Lake in the Superior National Forest, is threatening to repeat the widespread defoliation experienced a little over a decade ago. Another outbreak center has been reported for 1949 and 1950 in the eastern end of the Upper Peninsula of Michigan. Ultimately one or more of several natural

control factors will terminate these new threats. Among the more important natural population checks are parasitism, unfavorable weather (particularly late spring frosts), and starvation in areas where the caterpillars exhaust their food supply.

These outbreaks are expected to die out before there is extensive damage to aspen stands on good sites, but in the meantime there will be some tree mortality on poor sites, and property owners and tourists will be plagued with hoards of the pale bluish, spotted caterpillars which will denude roadside and shade trees and swarm over highways, buildings, and the unwary person who ventures under infested trees. For these reasons, control by aerial spraying with DDT is considered necessary and advisable only in areas of high value where resorts, private property, and scenic routes are likely to be invaded.

Occasionally aspen is defoliated seriously by one or more species of leaf beetles. The American poplar beetle, Phytodecta americana, the cottonwood leaf beetle, Chrysomela scripta, and two introduced species, C. tremulae and C. interrupta, are the most important. With the exception of the largest of these, C. tremulae, which has unmarked reddish-brown elytra (anterior wings), the elytra of the other species vary from yellow to red and are decorated with black spots or stripes. Young larvae are usually black or at least a very dark color, while older larvae are a dirty yellow color. The adults cut holes between the leaf veins, and the larvae may cause extensive damage by skeletonizing the leaf surface.

Four species of leaf rollers are found in aspen stands in the Lake States, the most important being the large aspen tortrix, Archips conflictana. The larvae of this insect feed in rolled leaves that are more or less funnel-shaped. Although there are feeding larvae present in the late summer, the heaviest damage is done in the spring when the larvae become active after hibernation. A few local outbreaks of this species have been observed in northern Minnesota near the north shore of Lake Superior. Another leaf roller called the poplar leaf-folding sawfly, Pontania bozemani, and two other species, P. populi and P. robusta, are found commonly but are of no economic importance. The pale green larvae fold the leaf margin and later the injured portion becomes blackened and unsightly. Additional leaf feeders may be found, but they are of little or no economic importance.

Several species of poplars may become infested with the poplar vagabond aphid, Mordwilkoja vagabundus, which causes a peculiar gall formation consisting of swollen and convoluted leaves at the tips of terminal twigs. Although these galls are not abundant in normal stands, they often become numerous after trees have been heavily defoliated, and in windbreak plantings. Another aphid, Pemphigus populi - transversus, causes the common poplar stem gall which is a globular swelling on leaf petioles. Other species of the same genus may cause similar galls on the leaves. None of them are of economic importance.

Wood Borers

The most important wood borer found in aspen is the common poplar borer, Saperda calcarata. This species attacks the trunks of trees, usually 3 inches or more in diameter, and also bores in the base of young trees at the root crown. During the three-year life cycle, the larvae form tunnels through the wood which cause breakage and ruin the wood for many purposes, particularly the production of veneer. A survey made in 1947 in northern Minnesota showed a high incidence of poplar borer damage at the base of young trees one inch or more in diameter. The percentage of trees infested in the many stands examined showed a strong relationship to site conditions, ranging from 70 percent or more on poor sites to less than 1 percent on good sites. No evidence of wood decay was found to be associated with this type of damage, but carpenter ants commonly occupied the tunnels after they had been vacated by the poplar borer. The presence of the borer can be detected in the forest by observing the fallen particles of woody frass which usually are very conspicuous on the leaves of undergrowth or on the ground litter below infested trees. In addition, the tunnel openings on the trunk usually are surrounded with a varnish-like stain on the bark.

Aspen also is attacked by the poplar-twig borer, Saperda moesta, and the poplar-gall saperda, Saperda concolor, both of which cause conspicuous gall-like swellings on small branches. No serious damage is likely under forest conditions, but shelterbelt plantings and ornamental trees sometimes are injured.

A species of Agrilus, now distinguished from the bronzed birch borer, is a common inhabitant of weakened and dying aspen. This species, A. liragus, generally forms compact, zigzag tunnels under the bark which are unlike the loose, winding galleries produced by the closely related bronzed birch borer, A. anxius. The flat-headed larvae of one or more species of the genus Dicerca are also common secondary invaders of dying and dead aspen, and one species of ambrosia beetle, Trypodendron retusus, is found in dead trees, particularly those that have died during the previous winter.

Scale Insects

Several species of scale insects may attack aspen and other poplars, although they have not caused any serious damage in the Lake States. Among the most common are the oystershell scale, Lepidosaphes ulmi; Putnam's scale, Aspidiotus ancylus; the scurfy scale, Chionaspis furfura; and the brown elm scale, Lecanium corni.

MAMMALS AND BIRDS WHICH DAMAGE ASPEN5/

Several species of animals feed upon aspen in the Lake States. Except for beaver and moose, few of them cause mortality to trees beyond seedling size. All these animals, however, cause injuries which retard growth and make the tree more susceptible to attack by fungi and insects.

In many instances the wildlife may be of greater value than the aspen, and the damage may, therefore, be justified economically. In other instances, wood production may be of highest value and control measures against wildlife species may be required. Ordinarily, where animal populations remain in balance with their environment, both wood and wildlife crops can be grown together.

Beavers use aspen as one of their favorite foods, although they feed also upon a number of other woody plants as well as aquatic vegetation. For food and for construction of dams and lodges, beavers will cut aspen trees up to 11 or more inches d.b.h. However, they prefer smaller trees averaging about 2 inches d.b.h. Since small trees are preferred, suckers often are eaten and regeneration thus prevented. Wild beavers in Michigan have cut an average of about 215 trees per year per animal. They may cut all the aspen within 500 feet of the home water course, although their operations usually are not over 300 feet from the stream. An acre of aspen probably will support an average colony of 5 beavers for 1 to 3 years. In addition to the trees cut, beavers also kill some aspen by flooding. Often suckering of aspen in flooded areas is prevented. Locally, therefore, beavers can cause considerable damage to aspen.

The white-tailed deer will eat aspen when other more favored browse is unavailable. Aspen has been ranked as a poor second choice or even starvation winter food. Ordinarily only small twigs and sprouts are eaten. However, where populations become high, deer may damage aspen reproduction quite extensively. A survey showed that 30 to 40 percent of the aspen reproduction in northern and central Wisconsin was heavily browsed by deer. Another study showed that aspen made up 25 percent of the winter browse consumed by deer in central Wisconsin; only willow was browsed more heavily. Because of their abundance and the reluctance of sportsmen to support adequate hunting pressure, deer probably will continue to damage much aspen reproduction in parts of the Lake States.

The snowshoe hare eats aspen sprouts and may girdle small trees. A survey disclosed that 5 to 10 percent of the aspen reproduction in northern Wisconsin had been browsed by hares. During the 2 or 3 years when the hares approach population peaks (about every 10 years), they undoubtedly destroy large numbers of aspen seedlings. At other times they may actually be beneficial through thinning dense clumps of sprouts. Within its range, the cottontail rabbit also browses on aspen.

5/ This and following sections were prepared by Paul O. Rudolf, Forester, Lake States Forest Experiment Station. Unpublished information was made available by L. W. Krefting of the U. S. Fish and Wildlife Service.

Moose browse aspen in preference to other plants as a winter food. Ordinarily they consume only twigs within their reach, but when populations become very high, as on Isle Royale, they bark and often kill standing trees. Reproduction also is consumed under those conditions. Since moose are found only in northern Minnesota and on Isle Royale, they will cause but little damage over the region. Elk, also rare in the Lake States, may strip aspen in a few localities.

Red squirrels, black bears, and porcupines also are reported to feed on aspen to a slight extent. Sheep and goats find aspen very palatable, and cattle also will browse aspen. Where abundant, domestic livestock can damage aspen considerably.

Ruffed grouse feed on aspen all year around. In the summer they feed largely on leaves, but in the fall, winter, and spring the grouse eat aspen buds. While this damage seldom is serious directly, it may retard growth and probably provides avenues of entrance for disease organisms and insects. Both the sharptailed and pinnated grouse feed on aspen buds in a similar manner, but they are much less abundant within the commercial range of aspen. The sapsucker, too, is known to do some damage to aspen.

CLIMATIC FACTORS

Although aspen is well adapted to the climate within its range, it sometimes is damaged seriously by storms. Periodic heavy windstorms have caused breakage in aspen stands over extensive areas in the northern Lake States. Breakage may be particularly heavy in badly cankered stands, but sound trees, too, are broken in the severe storms. Wet, heavy snows and glaze storms also cause heavy breakage at times.

Bad hail storms are known to cause numerous bruises on aspen stems. Hypoxylon pruinatum, which is known to infect aspen readily through bruises, may follow.

Severe droughts, such as were prevalent in the early 1930's, seldom kill aspen beyond the young seedling stage. However, they weaken the trees and predispose them to injury by insect or disease.

FOREST FIRES

Aspen now is the most abundant forest type in the Lake States. Largely as a result of the widespread forest fires which swept the region between 1870 and 1920. However, while fire favors the establishment of aspen and may even stimulate suckering in newly felled areas, it can be detrimental to established stands. Not only can fires kill merchantable aspen or weaken them so other agencies can kill them, but they can also reduce the productivity of stands below merchantable levels. A study in Wisconsin indicated that moderate or severe burns in aspen stands largely eliminated the prospects of their profitable management on all but the better soils (good sandy loams or finer in texture).

WHAT IS NEEDED

A large number of enemies of aspen are known, but there is little detailed knowledge concerning most of them. Because aspen has now assumed great importance as a source of wood, there is need for more knowledge about those enemies. Their extent, the conditions under which they become serious, possibilities and desirability of control, feasible methods of control where justified -- all of these need to be explored further and worked out specifically.

Results of current exploratory study of Hypoxylon pruinatum are about ready for dissemination. Doubtless they will point out promising leads for further study of this disease, now considered the most important enemy of aspen. Likewise, if aspen stands are going to be managed at all intensively, we shall need to know more about the other disease causing organisms, insects, mammals, birds, climatic factors, and fire which damage this tree.

REFERENCES FOR FURTHER READING ON ENEMIES OF ASPEN

Leaf Diseases

McCallum, A. W.
1920. Napicladium tremulae. A new disease of the poplar. (Abstract) Phytopathology 10: 318.

Pomerleau, R.
1940. Studies on the ink-spot disease of poplar. Canadian Jour. of Res., Sect. C, 18: 199-214.

Seaver, F. J.
1945. Sclerotinia bifrons. Mycologia 37: 641-647.

Thompson, C. E.
1939. A leaf blight of Populus tacamahaca Mill. caused by an unidentified species of Linospora. Canadian Jour. Res., Sect. C, 17: 232-238.

———
1941. Leaf-spot diseases of poplars caused by Septoria musiva and S. populicola. Phytopathology 31: 241-254.

Cankers

Bier, J. E.
1939. Septoria canker of introduced and native hybrid poplars. Canadian Jour. Res. Sect. C, 17: 195-204.

———
1940. Studies in forest pathology. III. Hypoxylon canker of poplar. Canadian Dept. Agr. Tech. Bul. 27.

Christensen, C. M.
1940. Studies on the biology of Valsa sordida and Cytospora chrysosperma. Phytopathology 30: 459-475.

Gruenhagen, R. H.
1945. Hypoxylon pruinatum and its pathogenesis on poplar. Phytopathology 35: 72-89.

Hartley, C., and Hahn, G. G.
1920. Notes on some diseases of aspen. Phytopathology 10: 141-147.

Kaufert, Frank

1937. Factors influencing the formation of periderm in aspen. Amer. Jour. Botany, 24: 24-30.

Schreiner, E. J.

1931. The role of disease in the growing of poplar. Jour. Forestry 29: 79-82.

_____

1918. Two species of Valsa causing disease in Populus. Amer. Jour. Botany 18: 1-29.

Thompson, G. E.

1939. A canker disease of poplars caused by a new species of Neofabraea. Mycologia 31: 455-465.

Waterman, Alma M.

1946. Canker of hybrid poplar clones in the United States, caused by Septoria musiva. Phytopathology 36: 148-156.

Decay

Hirt, Ray R.

1949. Decay of certain northern hardwoods by Fomes igniarius, Poria obliqua, and Polyporus glomeratus. Phytopathology 39: 475-480.

Horton, G. S., and Hendee, C.

1934. A study of rot in aspen on the Chippewa National Forest. Jour. Forestry 32: 493-494.

Meinecke, E. P.

1929. Quaking Aspen. A study in applied forest pathology. U. S. Dept. Agric. Tech. Bul. 155.

Schmitz, Henry, and Jackson, Lyle W. R.

1927. Heartrot of aspen, with special reference to forest management in Minnesota. Minn. Agric. Expt. Sta. Tech. Bul. 50.

Spaulding, Perley

1937. White trunk rot of hardwoods. Massachusetts Forest and Park Assn. Tree Pest Leaflet No. 20.

Riley, C. G., and Bier, J. E.

1936. Extent of decay in poplar as indicated by the presence of sporophores of the fungus Fomes igniarius Linn. Forestry Chron. 12: 249-253.

Verrall, A. F.
1937. Variation in Fomes igniarius (L.) Gill. Minn. Agric. Expt. Sta. Bul. 117.

General Reference Works on Forest Pathology

Baxter, Dow V.
1943. Pathology in forest practice. John Wiley and Sons, N. Y. 618 pp.

Boyce, J. C.
1947. Forest pathology. McGraw-Hill Book Co., N. Y. 550 pages.

Hubert, E. E.
1931. Outline of forest pathology. John Wiley and Sons, N. Y. 543 pp.

Insects

Barter, G. W., and Brown, W. J.
1949. On the identity of Agrilus anxius Gory and some allied species. Can. Ent. 81: 245-249.

Craighead, F. C.
1950. Insect enemies of eastern forests. U.S.D.A. Misc. Pub. 657, 679 pp.

Dils, R. E., and Day, M. W.
1950. Effect of defoliation upon the growth of aspen. Mich. Agr. Expt. Sta. Quart. Bul. 33(2): 111-113, illus.

Hodson, A. C.
1941. An ecological study of the forest tent caterpillar, Malacosoma disstria Hbn., in northern Minnesota. Univ. of Minn. Agr. Expt. Sta. Tech. Bul. 148, 55 pp.

Mammals and Birds

Aldous, Shaler E.
1938. Beaver food utilization studies. Jour. Wildlife Mgt. 2(4): 215-222, illus.

_____ and Krefting, Laurits W.
1946. The present status of moose on Isle Royale. Trans. 11th N. Amer. Wildlife Conf., pp. 296-308, illus.

Bailey, Vernon

1927. Beaver habits and experiments in beaver culture. U.S.D.A. Tech. Bul. No. 21, pp. 11-12, 32-34.

Bradt, G. W.

1947. Michigan beaver management. Mich. Dept. Cons. Game Div., pp. 28-33.

Edminster, Frank C.

1947. The ruffed grouse - its life story, ecology, and management. Pp. 125-126. Macmillan Company, N. Y.

Krefting, Laurits W., and Lee, Forest B.

1948. Progress report: Moose browse investigations on Isle Royale National Park, 20 pp. typescript.

_____, and Martin, Frank R.

1950. Special report: Deer browse survey of the Necedah National Wildlife Refuge, Necedah, Wisconsin. 18 pp. typescript.

Swift, Ernest

1949. Wisconsin's deer damage to forest reproduction survey - final report. Wis. Cons. Dept. Pub. 347, 24 pp., illus.

_____

1946. A history of Wisconsin deer. Wis. Cons. Pub. 323, page 60.

Forest Fires

Lake States Forest Experiment Station

1931. Fire hinders conversion of aspen to pine and spruce. Tech. Note No. 34, 1 page (proc.).

Stoeckeler, J. H.

1948. The growth of quaking aspen as affected by soil properties and fire. Jour. For. 46(10): 727-737, illus.